



Guidelines for Bicycle and Pedestrian Facilities in Texas

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IMPLEMENTATION STATEMENT

Bicycling and walking are becoming more popular means of transportation for commute trips and recreation travel in Texas and throughout the country. A number of factors are contributing to the increase use of these modes. Bicycling and walking provide alternatives to the use of motor vehicles, help address air quality concerns, improve opportunities for exercise and leisure activities, and enhance the quality of life in communities. As a result, greater use of bicycling and walking can benefit individuals, the environment, and communities.

To help realize these goals, bicycle and pedestrian projects must be planned, designed, and operated in a safe and efficient manner. This research study examines the use of these facilities and presents guidelines for planning and designing bicycle and pedestrian facilities on roadways and in separate rights-of-way. Information is also presented on supporting facilities that can encourage greater use of bicycling and walking.

The guidelines and information presented in this report will be of benefit to the Texas Department of Transportation (TxDOT), other state agencies, metropolitan planning organizations, transit agencies, cities, counties, and other groups interested in planning, designing, constructing, and operating bicycle and pedestrian facilities. The report also provides suggestions for implementing the guidelines and for encouraging more widespread development of bicycle and pedestrian projects.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes.

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SUMMARY

INTRODUCTION

Bicycling and walking have historically been important methods of transportation. The advent of the automobile, the construction of the freeway system, and the development of low density suburban areas, have all lessened the use of these modes. Recently, there has been renewed interest in Texas and throughout the country in bicycling and walking for commute trips and recreational activities. This interest has been generated by a desire to provide alternatives to driving, to address environmental concerns, to improve opportunities for exercise and leisure activities, and to enhance the quality of life in communities.

Recent federal and state legislation has also supported this renewed interest in bicycling and walking. The Clean Air Act Amendments of 1990 place requirements on air quality non-attainment areas, including reducing vehicle kilometers of travel. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 further supported the transportation provision of the Clean Air Act Amendments and provided new programs and funding for enhancement projects, including bicycle and pedestrian facilities. The Texas Department of Transportation (TxDOT) has been given additional responsibilities over the years related to bicycle and pedestrian facilities. Legislation passed in 1991 directs the Department to enhance the use of the state highway system by bicyclists.

This research project was undertaken to help address the renewed interest in bicycling and walking and TxDOT's additional responsibilities. The research project developed guidelines to assist TxDOT personnel and transportation professionals throughout the state, plan and design safe and efficient bicycle and pedestrian facilities.

RESEARCH APPROACH

Researchers conducted a number of activities during the study. A state-of-the-art literature review was conducted to assess current guidelines and issues. Reports from federal agencies, national organizations, other state departments of transportation, and bicycle organizations were examined. A survey of individuals and groups involved in planning, designing, and maintaining bicycle and pedestrian facilities in Texas was also conducted. The survey results, and subsequent panel discussions held in four areas, provided additional insights into the issues and opportunities associated with bicycle and pedestrian projects.

RESEARCH RESULTS

The results of this research study provide guidelines for planning and designing bicycle and pedestrian facilities in the state. The guidelines can be used by TxDOT personnel and other transportation professionals to plan and design safe and efficient bicycle and pedestrian projects.

Planning Guidelines

A 10-step process is presented for planning bicycle and pedestrian facilities. The 10 steps are highlighted below. The exact steps in the process will depend on the scope and scale of the effort, the facilities being considered, the institutional relationships in the area, and the characteristics of the area. The planning process outlined can be modified to meet the needs and conditions in a specific area.

- Identify and Involve Appropriate Groups
- Establish Goals, Policies, and Objectives
- Initiate and Continue Public Involvement
- Identify Alternatives
- Collect Data
- Analyze Alternatives
- Public Input on Alternatives
- Identify Preferred Plan or Alternatives
- Public Review
- Finalize Plan or Alternative

More detailed information on special considerations in planning bicycle and pedestrian facilities is also presented. These include examining the characteristics of different user groups, travel patterns and trip purposes, and possible safety concerns. Coordination with state, regional, and local plans and other elements are also described.

Design Guidelines

Design guidelines are presented for various types of bicycle and pedestrian facilities. The design features associated with bicycle facilities on new and existing roadways are described. These include widening general-purpose traffic lanes, bike lanes, and shoulders. Special considerations relating to intersections, signing, structures, and the roadway surface are highlighted. Design elements of bicycle paths, multi-use trails, and sidewalks are also highlighted.

Supporting Facilities and Services

The provision of supporting facilities and services can make bicycling and walking more attractive alternatives to individuals for commute trips and recreation travel. Bicycle racks or bicycle lockers at employment locations, major activity centers, and transit park-and-ride lots are commonly used to support bicycle travel. Bicycle racks on public transit buses, allowing bikes on rail transit vehicles, and providing showers and changing facilities at work sites represent other examples of supporting projects.

CHAPTER ONE—INTRODUCTION

BACKGROUND

Historically, bicycling and walking have been important methods of transportation. The advent of the automobile, the construction of the freeway system, and the development of low density suburban areas, have all lessened the use of these modes. Further, the roadway, land use, and development patterns in many areas have made bicycling and walking difficult, if not impossible.

There has been renewed interest recently in Texas and throughout the country in bicycling and walking for commute trips and recreational activities. This interest has been generated by a number of factors. These include providing alternatives to driving, addressing environmental concerns, improving opportunities for exercise and leisure activities, and enhancing the quality of life in communities.

Recent federal and state legislation and initiatives have also supported this renewed interest in bicycling and walking. For example, the Clean Air Act Amendments of 1990 place requirements on air quality non-attainment areas, including reducing vehicle kilometers of travel. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 further supported the transportation provision of the Clean Air Act Amendments and provided new programs and funding for enhancement projects, including bicycle and pedestrian facilities. A recent Federal Highway Administration (FHWA) report recommends actions to double the number of trips made by bicycling and walking from the current 8 percent to 16 percent and to reduce the number of bicycle and pedestrian fatalities by 10 percent (1).

At the state level, the Texas Department of Transportation (TxDOT) has been given additional responsibilities over the years related to bicycle and pedestrian facilities. For example, legislation passed in 1991 directs the Department to enhance the use of the state highway system by bicyclists. To help address the renewed interest in bicycling and walking, and TxDOT's additional responsibilities, the Department initiated a research study to examine the use of these facilities. The research project was oriented toward developing guidelines to assist TxDOT personnel and transportation professionals throughout the state plan, design, and operate safe and efficient bicycle and pedestrian facilities.

OBJECTIVES OF RESEARCH STUDY

This research study was undertaken to provide information to TxDOT personnel, transportation professionals throughout the state, and other groups on planning, designing, operating, and maintaining bicycle and pedestrian facilities. The research examined the current state-of-the-practice relating to planning and designing bicycle lanes and paths, multi-use trails, and pedestrian facilities. The safety and operating issues associated with the use of these facilities by bicyclists, pedestrians, and motor vehicles were also examined. The research results, presented in this report, provide guidelines for planning and designing various types of bicycle and pedestrian facilities. The

guidelines should be of benefit to TxDOT personnel and other individuals responsible for planning, designing, operating, and maintaining bicycle and pedestrian facilities.

RESEARCH ACTIVITIES

Researchers conducted a number of activities to accomplish the previous objectives. First, a state-of-the-art literature review was conducted. Reports from federal agencies (2,3,4), national organizations, and other state departments of transportation were examined, along with articles relating to planning, designing, and operating bicycle and pedestrian facilities. The reports developed in Arizona (5), California (6), Florida (7), Minnesota (8), North Carolina (9), and Oregon (10), as well as those prepared by the American Association of State Highways and Transportation Officials (AASHTO) (11), the Institute of Transportation Engineers (ITE) (12), the American Planning Association (APA) (13), and the North Central Texas Council of Governments (NCTCOG) (14), provide good examples of current guidelines and information.

Researchers also conducted a survey of individuals and groups in Texas involved in planning, designing, and maintaining bicycle and pedestrian facilities. The survey results, and subsequent panel discussions held in four areas, provided additional insights into the issues and opportunities associated with planning, designing, and operating bicycle lanes and paths, multi-use trails, and pedestrian walkways.

The results of all these activities were used to develop the guidelines presented in this report. Information is presented on planning bicycle and pedestrian facilities; design features of bicycle lanes, bicycle paths, multi-use trails and pedestrian walkways; and supporting facilities which may be considered to encourage bicycling and walking. The guidelines can be used by TxDOT personnel, transportation professionals, and other individuals to help promote the safe and efficient development and use of bicycle and pedestrian facilities in the state.

ORGANIZATION OF REPORT

This report is divided into six chapters following the introduction. Chapter Two provides an overview of the process for planning bicycle and pedestrian facilities. Chapter Three discusses the approaches and design techniques that can be used to accommodate bicycles on existing and new roadways. The design features associated with separate bicycle paths and multi-use trails are presented in Chapter Four. Chapter Five outlines the special elements to be considered in designing sidewalks and pedestrian walkways. The use of supporting facilities to encourage bicycling and walking is discussed in Chapter Six. The report concludes with the identification of strategies and techniques that can be used to encourage the implementation of the guidelines. The Appendices provide a glossary of commonly used terms related to bicycle and pedestrian facilities, an example of a survey used to obtain information on bicycle and pedestrian use, and a copy of the Texas Department of Public Safety's Pedestrian and Bicycle Laws and Safety Guidelines.

CHAPTER TWO—PLANNING BICYCLE AND PEDESTRIAN FACILITIES

This chapter provides an overview of the steps involved in planning bicycle and pedestrian facilities. A general process for planning bicycle lanes and paths, multi-use trails, and walkways is presented first. Special considerations in planning bicycle facilities are then summarized, followed by unique features associated with planning pedestrian walkways. Appendix A provides a glossary of the terms commonly used in planning and designing bicycle and pedestrian facilities.

OVERVIEW OF PLANNING PROCESS

The general process for planning any type of bicycle or pedestrian project commonly involves ten steps. These elements are highlighted in Figure 1 and described below. The exact steps in the process will depend on the scope of the effort, the facilities being considered, the institutional relationships in the area, and the characteristics of the area. The planning process outlined here can be modified to meet the needs and conditions in a specific area.

Identify and Involve Appropriate Groups

The first step in the planning process is to ensure that all of the appropriate groups are involved in the effort. The exact agencies and organizations to include in the planning process will vary by area and by the type of facilities being considered. The information presented here can be used to help identify the agencies and groups that may be appropriate to include in the planning process for a specific project, as well as in the development of a regional or a community-wide bicycle and pedestrian plan.

In many cases, consideration may be given to forming a multiagency committee or team to develop a regional bicycle and pedestrian network or to plan a specific project. This approach is commonly used in many areas for all types of transportation projects, including bicycle and pedestrian facilities. Multiagency teams help ensure that all the appropriate groups are involved in the planning process, that coordination occurs between various governmental levels and among local jurisdictions, and that the resources of the various groups are maximized and duplication of effort is minimized.

The agency with the overall responsibility for the plan or project usually takes the lead role in organizing and staffing these committees. For example, TxDOT is the logical agency to lead the development of a statewide plan, a Metropolitan Planning Organization (MPO) is the appropriate agency to organize a committee to develop a regional plan, and a city is the obvious group to lead a citywide plan. Coordination should also occur among the planning efforts at these different levels. For example, a regional plan should be consistent with the statewide plan, and local plans and projects should be consistent with the regional plan.

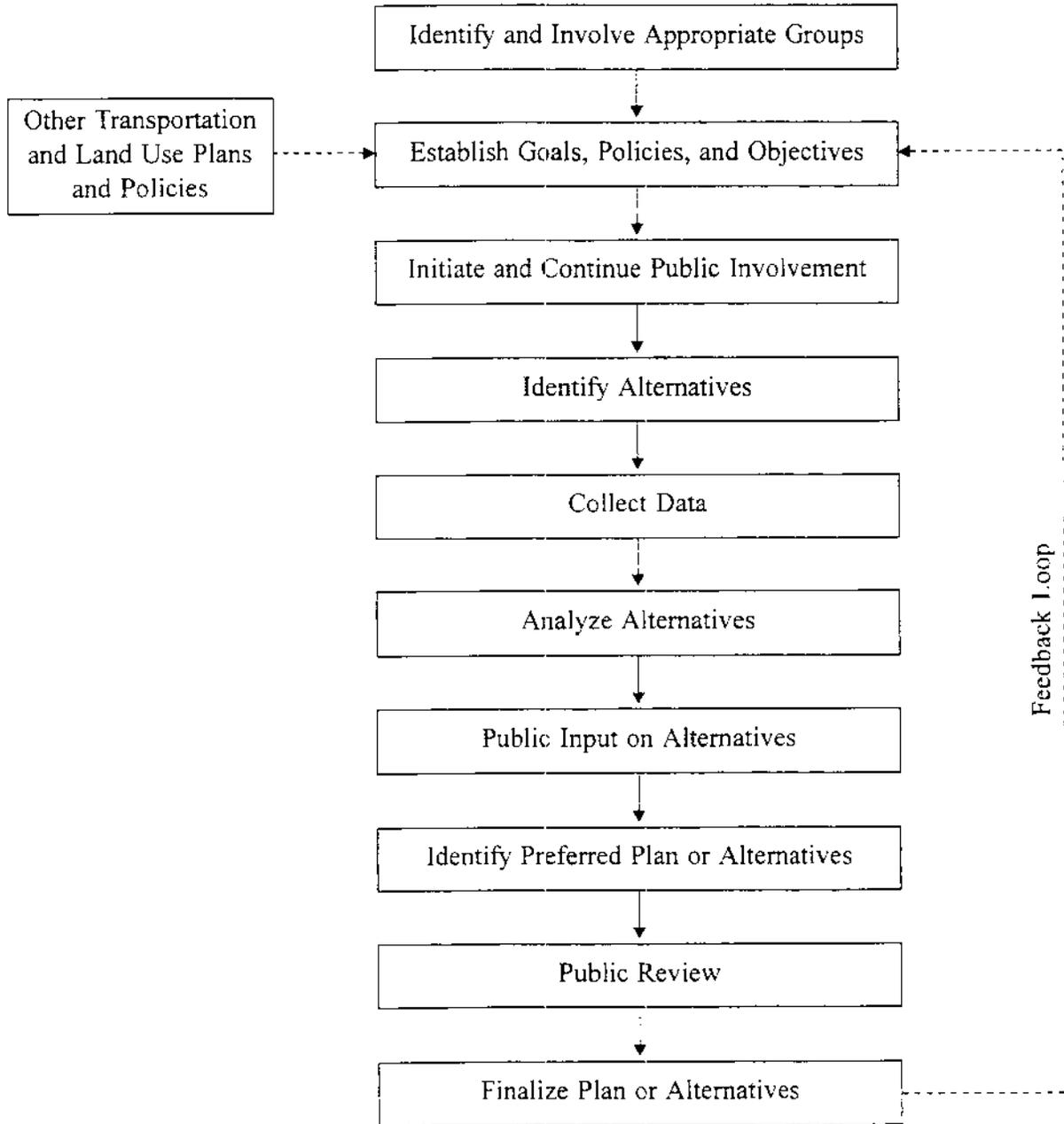


Figure 1. General Steps in Planning Bicycle and Pedestrian Facilities

Texas Department of Transportation (TxDOT). TxDOT has overall responsibility for bicycle and pedestrian facilities on state-owned roadways. However, sidewalks are the responsibility of local units of government within city limits. Bicycle and pedestrian facilities are also included in TxDOT's statewide transportation plan. In addition, TxDOT may provide support to communities or other groups planning projects on local roadways or in separate rights-of-way. These efforts often need to be coordinated with TxDOT projects on state roadways or with federal funding administered by the Department.

Metropolitan Planning Organizations (MPOs). MPOs are responsible for the development of the regional long-range transportation plan, as well as the project selection process and the short-range Transportation Improvement Program (TIP). The need for bicycle and pedestrian facilities will be considered in the development of these plans. The long-range plan should include bicycle and pedestrian components. A special regional bicycle and pedestrian planning effort may be undertaken if the current plan does not adequately address these facilities. Specific projects to be implemented by all levels of government with the region will be programmed in the TIP.

Local Jurisdictions. Cities and communities have responsibility for planning, designing, constructing, operating, and maintaining bicycle and pedestrian facilities on local roadways, as well as in city and county parks or other separate rights-of-way. These efforts should be coordinated with TxDOT and with projects on state-owned roadways. Local communities should also be involved with projects on state roads. In these cases, personnel from local jurisdictions may participate on multiagency teams or may help coordinate state and local activities.

Transit Agencies. Transit agencies in the state may be involved in planning bicycle and pedestrian facilities. For example, some of the Metropolitan Transit Authorities (MTAs) have general mobility programs or other efforts that fund improvements on streets and roadways. Bicycle lanes, bike paths, multi-use trails, and pedestrian walkways may be considered for funding under these programs. In addition, most transit agencies provide racks or lockers for bicycles at park-and-ride lots and may have bicycle racks on buses or allow bicycles on light rail transit (LRT) vehicles.

Bicycling and Hiking Groups. Many areas have active bicycling, hiking, or other groups that will have an interest in planning, designing, and operating bicycle and pedestrian facilities. Involving representatives from these organizations early and throughout the planning process can have numerous benefits. Individuals from these groups can help identify issues and opportunities related to specific projects, assist in estimating the demand for different facilities, and provide other ideas and suggestions.

General Public, Neighborhood Groups, Universities, Schools, and Businesses. The public participation process represents an important component of any planning effort. Like bicycle and hiking groups, representatives from these organizations should be involved early

and throughout the planning process. This involvement can help ensure that potential concerns are identified early in the planning process and that techniques to address them are developed. Representatives from these groups can also provide ideas and suggestions on alternatives, potential use, utilization levels, and links to other projects.

Developers. Developers of residential, retail, commercial, and business land uses may be required to construct bicycle and pedestrian facilities. The type of requirements and the nature of the facilities to be provided will usually be identified in a community's land use plan and zoning ordinance.

Consultants. Private consulting firms may be hired to develop bicycle and pedestrian plans, conduct specific studies, design projects, or assist with other tasks.

Establish Goals, Policies, and Objectives

The planning process will be guided by the goals, policies, and objectives developed and adopted by the appropriate governing boards or groups. These may include state commissions, MPO boards, city councils, transit agency boards, and other organizations. The goals and policies should provide a future vision for the transportation system, including bicycle and pedestrian facilities for the state, region, or community. The development of goals, policies, and objectives may be influenced by legislation and plans at other levels. For example, the development of state transportation goals and policies will be influenced by federal directives, while local goals and policies will be guided by state and MPO plans.

Goals, policies, and objectives represent a cascading level of detail. Goals provide the long-term vision for a state, region, or community. Policies help direct and focus actions to meet these goals. Objectives represent specific, measurable activities that will be undertaken to accomplish the stated goals and policies.

The development of goals, policies, and objectives is not an easy process. Public involvement is critical in establishing meaningful and realistic goals and policies. The identification of objectives that include measurable criteria and time lines is not always easy. Developing realistic goals and policies that reflect the values and the vision of a community, as well as measurable objectives, will have long term benefits and represent the basis of a good planning process.

Initiate and Continue Public Involvement

The public should be involved throughout the planning process for bicycle and pedestrian facilities. Providing opportunities early and throughout the planning process for participation from representatives from neighborhood groups, bicycle and pedestrian organizations, the public, and other groups can help ensure that relevant issues are identified and that appropriate alternatives are considered. It can also assist in reaching a consensus on specific projects or an overall plan. A variety of techniques can be used to elicit public involvement including surveys, focus groups, meetings, forums, workshops, hearings, public access television, and other approaches.

Identification of Alternatives

The next step in the planning process is to identify potential alternatives that will accomplish the established goals, policies, and objectives. The nature and number of alternatives will depend on the scope and scale of the project. For example, the scope of a planning process to develop a regional bicycle network will be much more complex than examining alternatives on one segment of an existing roadway. Usually, a number of possible alternatives are identified for consideration. The criteria to be used to evaluate the alternatives are often developed during this step.

Data Collection

Once the alternatives have been identified, the data needed to analyze the options are collected. Available information on bicycle use, traffic counts, land uses, development patterns, and major activity centers may all be used in the analysis process. In addition, special surveys of bicyclists and walkers may be conducted to obtain more detailed information.

The data collection effort should be matched to the scope and scale of a project. The use of available information should also be maximized. In many cases, additional surveys or data collection activities will be needed to provide current and accurate information for the planning process. The following information sources and surveys provide examples of the techniques that can be used for specific planning studies.

Census Data. Census data can be used to identify the number of individuals living in various areas, automobile ownership, income levels, and commute modes. Since the census is conducted only once every ten years, however, the available information may be outdated. Even in these cases, the census does represent a good source of basic and easily obtainable information.

Traffic Counts. Available traffic counts and other traffic data can be used to identify roadways that may or may not be appropriate for bicycle and pedestrian facilities. For example, roadways with high volumes of trucks or motor vehicles and high speeds are probably not appropriate for bicycle use. On the other hand, roadways with lower traffic volumes and travel speeds represent more likely candidates.

Accident Records. Available information on accidents involving bicyclists or pedestrians can be used during the planning process to identify unsafe or hazardous areas. Accident records from the Department of Public Safety (DPS) or local police provide the best sources of this information. In addition, information from local hospitals may be available on the treatment of bicyclists or pedestrians involved in accidents. The types of accidents commonly involving bicyclists and pedestrians are described later in this chapter.

Aerial Photographs. Aerial photographs can provide a good deal of information for use in the planning process. These photographs show the local and regional roadway system, residential areas, major activity centers, parks, and other land use features. This information

can be used to identify logical roadways for bicycle lanes, possible rights-of-way for bicycle paths and multi-use trails, and other features.

Land Use Maps. Along with aerial photographs, land use maps provide an indication of existing and future land use patterns. Land use maps, comprehensive plans, and zoning ordinances and maps can be used to identify current and future demands for bicycle and pedestrian facilities.

Bicycle and Pedestrian Counts. Special counts of bicycles and pedestrians may be conducted during the planning process to develop a baseline of current use and to help identify areas of future demand. A procedure should be developed for conducting special counts. Elements to consider in this process include identifying locations for the counts, developing procedures for manual or electronic counting, and establishing the data collection time period. Manual techniques involve stationing an individual at a location to count and record the number of bicyclists and pedestrians. Electronic methods include the use of pressure sensitive tubes or video cameras. In the latter case, the video tapes are replayed in the office, and the number of bicyclists or pedestrians are recorded. The data collection schedule will vary by facility type. For example, the counting period will be different for roadways used by bicyclists commuting to work than for bicycle trails used for recreational purposes. It is important that consistent methodologies and techniques are used and that a safe environment is provided to individuals conducting manual counts.

User Surveys. Bicycle and pedestrian counts will help provide an indication of current use. They will not identify latent demand or assist in documenting issues or opportunities. Surveys of bicyclists, walkers, and other individuals will need to be conducted to obtain this information. A number of survey and interview techniques can be used to gain input from current and future user groups. Personal interviews may be conducted along existing facilities or bicyclists and walkers may be given surveys to complete and mail in. An example of a postcard survey is provided in Appendix B. Questions on bicycle and pedestrian facilities may be added to a community survey being conducted as part of a comprehensive planning process or other study. Finally, special telephone or mailout surveys could be used. Although surveys can be expensive and time consuming to conduct, they can provide needed information for a project. Care should be taken to select the best technique for the project and to ensure that the survey is designed to obtain unbiased results.

Condition Inventory. A survey can also be conducted to develop a condition inventory on the roadways, paths, trails, and sidewalks being used by bicyclists and pedestrians, as well as those being considered for future use. A condition inventory should include maps or diagrams identifying pavement quality, drainage grates, and other hazards. Techniques used to develop conditions inventories include on-site observation, videotaping the area and reviewing it later, and examining existing records.

Analyze Alternatives

In this step, the alternatives being considered are analyzed based on the criteria and the information obtained in the previous steps. The level of detail and the length of time needed to analyze the alternatives will depend on the scope and scale of the project or plan, the number of alternatives, and the magnitude of issues in the area. General criteria that can be used to help identify the most appropriate alternatives are discussed later in the chapter.

Public Input on the Alternatives

The alternatives being considered are presented to the public and other groups during this step. In some cases, an initial screening process may be completed in the previous step to narrow down the alternatives to those that are most realistic for further consideration. These options are then presented to the public, bicycle and pedestrian groups, neighborhood organizations, and other interested groups with an explanation of the alternative development and evaluation process. Techniques that can be used to present the information and to obtain feedback include meetings, forums, workshops, hearings, newsletters, cable television, and other methods.

Identification of Preferred Alternative or Plan

Based on the results of the alternatives analysis and input from the public, the preferred option or plan can be selected. The preferred alternative usually meets the largest number of objectives within the available financial resources. Potential funding sources and the availability of financial resources for a project or plan may be one of the criteria used in the evaluation process.

Public Review

The recommended alternative is presented to the public for review and comment. Public meetings, newsletters, workshops, open houses, forums, and cable television represent just a few methods that can be used to communicate the recommended alternative to the public and to obtain feedback and input.

Finalize Plan or Alternatives

Based on the results from the public review process, the appropriate policy board or administrator can select the final alternative. Formal action approving or endorsing a specific alternative or course of action may be taken by the policy board or administrative staff within the responsible agency. The project development process, which includes finalizing funding, design, and construction of the project, can then be initiated.

SPECIAL CONSIDERATIONS IN PLANNING BICYCLE FACILITIES

A number of elements should be considered in developing and analyzing possible alternatives for various types of bicycle facilities. These include examining the characteristics of bicycle user

groups, travel patterns and trip purposes of bicyclists, and potential safety concerns. Further, how a project fits into an overall bicycle network or system should be considered, along with coordinating the facility with other projects. Each of these factors is discussed in this section. In addition, general planning criteria are presented to assist in determining the most appropriate types of bicycle facilities based on different characteristics.

Bicycle User Groups

The planning process should consider the characteristics of the different bicycle user groups. Variations exist in the skill levels of individual bicyclists. These variations will influence the behavior of bicyclists, which will need to be considered in planning, designing, and operating bicycle lanes, paths, and trails. Three general categories—Proficient Bicyclists, Basic Bicyclists, and Novice Bicyclists—are often used in planning and designing bicycle facilities (14,15). The characteristics associated with bicyclists in these three categories are described next.

Proficient Bicyclists. This category of bicyclists includes individuals who ride on a regular basis and have high skill levels. These may include individuals who regularly commute to work or school by bicycle, serious recreational bicyclists, and bicycle couriers or police patrols. These individuals are likely to travel at moderate to high speeds and are usually able to handle more difficult riding environments. Further, this group is often interested in being able to reach multiple destinations by bicycle, as well as using recreational paths and trails. Proficient riders represent a minority of the bicycling population in most areas.

Basic Bicyclists. The second common category used to characterize bicyclists is basic riders. This category includes new and infrequent or periodic riders. Characteristics associated with individuals in this group include lower skill levels than proficient bicyclists, slower travel speeds, avoidance of difficult riding environments, and shorter distance trips.

Novice Bicyclists. The final user group is comprised of novice bicyclists. These are individuals with little or no riding experience. First time users, young children, and very infrequent riders represent examples of novice bicyclists. Individuals in this group often have low skill levels and may be hesitant riders. Further, novice bicyclists may be less able to negotiate travel on roadways or other situations involving mixed traffic.

Travel Patterns

The travel patterns of bicyclists should be considered in the planning process for both regional bike networks and for specific projects. Identifying the major origins and destinations of bicyclists is an important step in developing a comprehensive bicycle system and planning individual projects. Major employment and retail centers, universities, and schools, represent just a few of the likely destinations for bicyclists. As discussed in the previous section, existing information sources and special surveys can be used to identify likely origins, destinations, and travel patterns of bicyclists.

Trip Purpose

The planning process should also consider the trip purpose of bicyclists. Trip purpose is related to the travel patterns of bicyclists and the characteristics of different user groups. Different types of trip purposes are often best served by different types of bicycle facilities. For example, recreational bicycle travel is best accommodated on separate bicycle paths or multi-use trails, while work or school trips will usually need to be made at least partially on the local street system. The data collection process described previously should provide information on the trip purpose of bicyclists. This information can then be matched with the alternatives being considered to identify the most appropriate facilities.

Safety Concerns

Possible safety concerns with the use of various types of bicycle facilities should also be considered in the planning process. The goal of the planning and design process is to develop facilities that are safe for bicyclists, motor vehicles, and other user groups. The following types of accidents are frequently encountered with various bicycle facilities (7).

Bicycle Crashes. The most common types of accidents involve an individual bicyclist losing control, bicyclists running into each other, or bicycle/pedestrian conflicts. A rider may fall or crash due to losing control, going off the road or path, hitting an obstruction, skidding on wet pavement, or other accident. Further, bicyclists may collide or a bicyclist may hit a pedestrian.

Intersections or Trail Junctions. Accidents involving bicycle and motor vehicles are more likely to occur at intersections and trail junctions than along a roadway. For example, a four year study in Palo Alto, California found that 74 percent of the reported accidents involving bicycles and motor vehicles occurred at intersections. Other types of accidents involving bicycles and motor vehicles include bicycles emerging from driveways, alleys, or mid-block locations; motorists turning into bicyclists at intersections, alleys, or mid-block locations; and bicyclists or motor vehicles making unexpected turns or swerves.

As noted previously, information on accidents involving bicyclists may be available from the local police, the DPS, and other groups. Problems may exist with accident data, however. For example, some accidents may never be reported to the police. Further, accident records may not always be complete or it may not be possible to determine the exact cause of an accident.

Bicycle Networks or System

Planning for a specific project should be coordinated with a comprehensive bicycle plan if one exists for the state, region, or community. The plan should define a network or system of bicycle facilities for the area. In other cases, the planning process may be focused on the development of a bicycle network and plan. In most cases, a mix of facilities will be used to develop a bicycle system. The following three factors should be considered in planning an areawide bicycle system.

Connectivity. A bicycle system should connect major residential areas, developments, and activity centers to allow bicyclists to travel between most significant origins and destinations.

Continuity. A bicycle network should not have major gaps or barriers. Rather a continuous system should be provided.

Accessibility. A bicycle network should be accessible to basic and proficient user groups.

Coordination with Other Projects and Plans

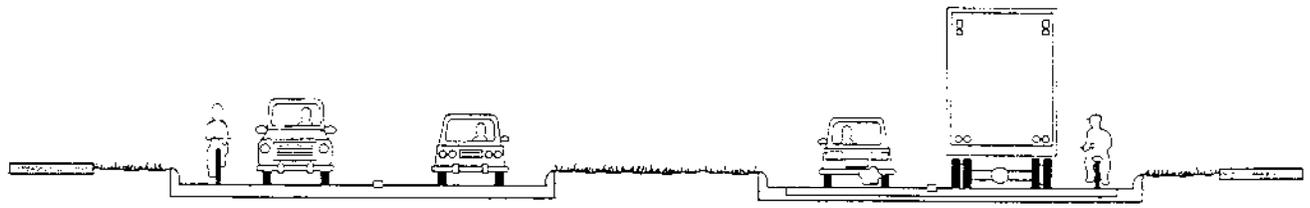
The planning process for a specific bicycle facility or a comprehensive bicycle plan should be coordinated with other projects and plans. For example, the development of a bicycle system plan should be coordinated with transportation, land use, and development plans at the state, regional, and local levels. Further, opportunities may arise to incorporate bicycle facilities into other roadway or land use projects. Ongoing communication and coordination among all groups responsible for bicycle, roadway, and land use projects can help ensure that potential opportunities for enhancing bicycle facilities are identified and maximized.

General Criteria for Planning Bicycle Facilities

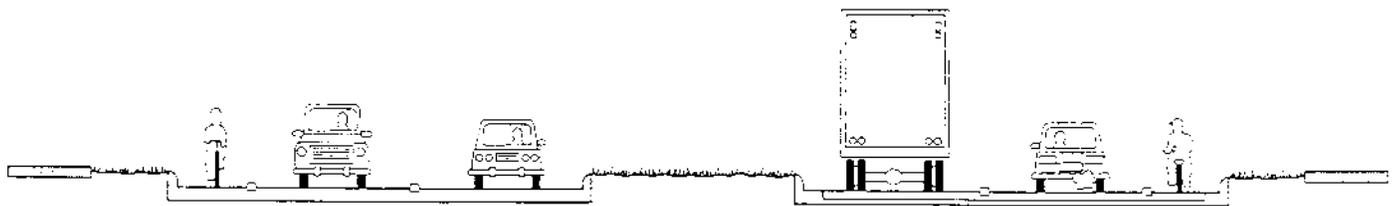
There are three general types of treatments used to accommodate bicycles on existing or new roadways. These are widening the outside general-purpose traffic lane, separate bicycle lanes, and using the shoulder. In addition, bicycle or multi-use paths or trails may be developed in separate rights-of-way. These alternatives are illustrated in Figure 2. The characteristics associated with the different techniques are described below, along with examples of situations where each is most appropriate. These general criteria are also presented in Table 1. The criteria provide a general indication of the factors that should be considered in the planning process. Transportation professionals can use these as a guide during the planning process and can modify the criteria to reflect the goals, objectives, and conditions for a specific project.

Sharing a Wide General-Purpose Lane. In this approach, bicycles share a widened outside general-purpose travel lane with other motor vehicles. The extra width provides space for motor vehicles to pass bicyclists without moving into the adjacent lane. Criteria for the consideration of widening outside lanes include low traffic volumes, low truck volumes, low speeds, low to moderate anticipated bicycle use, and proficient riders making non-recreational trips.

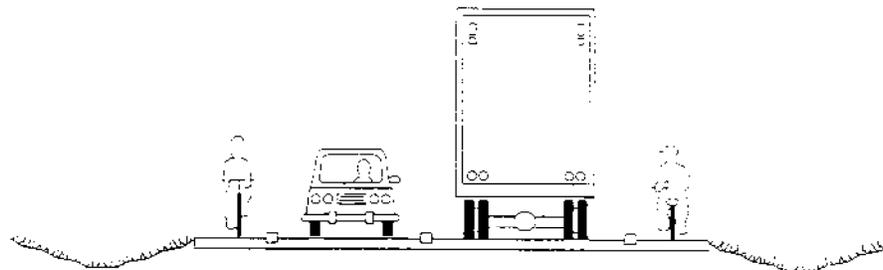
Bicycle Lanes. This approach provides a separate lane on a roadway reserved exclusively or primarily for bicyclists. Bike lanes are located on the right side of the roadway adjacent to the general-purpose lanes. Criteria for considering a bicycle lane include moderate traffic and truck volumes, moderate speeds, moderate to high anticipated bicycle use, proficient and basic riders, and commuting and recreational trip purposes.



Widened General-Purpose Lane



Bike Lane



Shoulder Use by Bicyclists



Two-Way Bike Path

Figure 2. Types of Bicycle Facilities

Table 1. General Criteria for Planning Bicycle Facilities

Criteria	Type of Bicycle Facility				
	Roadway Right-of-Way			Separate Right-of-Way	
	Wide General Purpose Lane	Bike Lane	Shoulder	Bike Path	Multi-Use Trail
Traffic volumes	Low	Moderate	Moderate	High	High
Truck volumes	Low	Moderate	Moderate	High	High
Motor vehicle speed	Low	Moderate	Moderate	High	High
Bicycle use	Low/moderate	Moderate/high	Low/moderate	High	High
Trip purpose	Commuting	Commuting/ recreational	Commuting/ recreational	Recreational/ commuting	Recreational/ commuting
User groups	Proficient bicyclists	Proficient and basic bicyclists	Proficient bicyclists	Proficient, basic, and novice bicyclists	Proficient, basic, and novice bicyclists

Shoulders. Shoulders may also be used in some areas for bicycles. Criteria for considering shoulder use by bicycles include roadways with low to moderate traffic and truck volumes, moderate speeds, and low to moderate number of bicycles. Shoulders are most commonly used by proficient bicyclists for commuting or recreational trip purposes.

Bicycle Paths and Multi-Use Trails. This approach involves the development of paths or trails on a separate right-of-way for use by bicycles or by bicycles, walkers, joggers, rollerskaters, and other groups. Bicycle paths and multi-use trails may be located adjacent to roadways, in parks, in abandoned railroad rights-of-way, and other areas. Criteria for considering separate bicycle or multi-use facilities include high volumes of all types of bicyclists and other user groups for recreational travel and commute trips. Separate facilities should also be considered adjacent to high volume and high speed roadways.

SPECIAL CONSIDERATIONS IN PLANNING PEDESTRIAN FACILITIES

A number of elements should be included in assessing the need for various types of pedestrian facilities and in analyzing alternative improvements. These include examining the characteristics of pedestrian user groups, assessing pedestrian travel patterns and trip purposes, and examining possible safety concerns. Further, how a project fits into an overall pedestrian network should be considered, and a facility should be coordinated with other plans and projects. Each of these elements is briefly described in this section. The level of service concept, which can be used in planning pedestrian facilities, is also discussed in this section.

Pedestrian User Groups

Pedestrians are frequently classified by age and by special needs. Individuals of different ages will have different capabilities, skills, and stamina. In addition, individuals with special needs, which may require the use of wheelchairs, walkers, or other support devices, will have different requirements. The following general categories can be used to assist in planning and designing various types of pedestrian facilities (14, 16).

Children. Young children and those in grade school are generally developing many of their motor and perceptual skills. These include their awareness of sounds, the direction of sounds, peripheral vision, concentration levels, and understanding of traffic dangers and other hazards.

Adults. This age group, which generally includes individuals from the high-school years through retirement, represents a significant portion of the population. In general, individuals in this age group have good walking skills and abilities.

Senior Citizens. Individuals in this group may begin to experience slower reaction times, as well as declines in walking speed, agility, eyesight, and stamina.

Individuals with Special Needs. This group may include individuals with sight or hearing problems, as well as those needing wheelchairs, canes, or other assistance. Individuals with special needs may experience difficulties using pedestrian facilities.

Pedestrian Travel Patterns

The travel patterns of pedestrians should be considered in the planning process for both regional pedestrian networks and for specific projects. Identifying the major origins and destinations of pedestrians is an important step in developing a comprehensive sidewalk and walkway system, and in planning individual projects. This process should examine both trips made solely by walking, as well as those where walking is just one component of the overall trip. This last group represents an important element in the planning process, since walking is part of many trips made by motor vehicles, public transit, and other modes. As discussed previously, existing information sources and special surveys can be used to identify likely origins, destinations, and travel patterns of pedestrians.

Logical areas of high pedestrian traffic include residential neighborhoods, schools and universities, commercial and retail centers, hospitals, and major employment concentrations. The downtown area, commonly referred to as the Central Business District (CBD), neighborhood shopping areas, and other special generators usually have high volumes of pedestrians. Special consideration may be given to pedestrian walkways in these areas. For example, skywalks, tunnels, and pedestrian or transit malls are used in some downtown areas to enhance pedestrian movement.

Trip Purpose

The planning process should also examine the trip purpose of pedestrians, which is related to the travel patterns and the characteristics of different user groups. The type of pedestrian facilities being considered should be matched to the anticipated trip purposes. Sidewalks and walkways can best link major activity centers and serve work and school trips. Separate hiking trails or multi-use paths can best serve recreational trips. The data collection process described previously should provide information on the trip purpose of pedestrians. This information can then be matched with the alternatives being considered to help identify the most appropriate facilities.

Safety Concerns

The planning process should examine potential safety concerns with the use of various types of pedestrian facilities. The desired goal of the planning and design process is to provide a safe environment for pedestrians and other user groups. In order to accomplish this goal, consideration should be given to the following types of accidents that are frequently encountered with different pedestrian facilities (16).

Mid-Block Dart-Out or Crossing. These types of accidents involve an individual darting out into the street or crossing a street at mid-block. The individual, often a child, may run or walk out from between parked cars into the path of an oncoming vehicle.

Intersection Dart-Out or Crossing. These accidents involve individuals crossing or darting out into an intersection and into the path of an oncoming vehicle.

Turning Vehicles. These accidents involve a pedestrian being hit by a motor vehicle making a turn at a driveway, intersection, or other access point.

Other Vehicles. Other types of accidents may occur at bus stops, service delivery areas, or with ice cream vendors in neighborhoods.

Pedestrian Networks or Systems

Planning for a specific project should be coordinated with a comprehensive pedestrian system plan if one exists at the state, region, or local levels. This plan should define a network of pedestrian facilities for the area, which will usually represent a mix of sidewalks, walkways, paths, and multi-use trails. In other cases, the planning process may be developing a comprehensive pedestrian plan. Similar to a bicycle plan, the following three factors should be considered in planning an areawide pedestrian system.

Connectivity. A pedestrian system should connect major residential areas, retail and commercial centers, employment areas, and other developments to help link significant origins and destinations.

Continuity. A pedestrian system should not have major gaps or barriers in logical walkable areas. A continuous system should be provided within and between areas.

Accessibility. A pedestrian system should be accessible to all user groups.

Coordination with Other Projects and Plans

The planning process for a specific pedestrian facility or a comprehensive pedestrian plan should be coordinated with other projects and plans. These include transportation, land use, recreation, and development plans at the state, regional, and local levels. Coordination with community comprehensive and land use plans, and zoning ordinances, is especially critical. The authority to regulate land uses and to require sidewalks and other pedestrian facilities rests primarily with local municipalities. As a result, city staff should be actively involved in the planning process for both regional pedestrian systems and specific projects.

Ongoing coordination among agencies and groups can also help identify opportunities to incorporate pedestrian facilities into new and existing roadway and development projects. This ongoing communication and coordination among all groups responsible for pedestrian, roadway, and land use projects can help ensure that potential opportunities for enhancing pedestrian facilities are identified and maximized.

Pedestrian Level of Service

Pedestrian Level of Service (PLOS) is a concept modeled after the *Highway Capacity Manual's* motor vehicle level of service (LOS) (17). This concept is based on a hydraulic flow model, combined with density considerations. The more dense the flow of pedestrians or motor vehicles, the slower the speeds. The relationships for motor vehicles and pedestrians are similar, although the units of measure are different.

The PLOS presented in the *Highway Capacity Manual* (17) can be used to assist with designing pedestrian facilities. Variables included in the calculation of PLOS are pedestrian volumes, pedestrian densities, and the effective walkway width. Pedestrian volumes and densities relate to walking speeds, ability to pass other pedestrians or cross pedestrian traffic, walking in the reverse direction of the main pedestrian flow, and maneuvering without conflicts or changes in walking speed.

The underlying assumption of the PLOS concept is that pedestrian movement should be continuous and relatively uniform. Further, PLOS assumes that pedestrian capacity is reduced when obstructions are present in the walkway. These may include parking meters, trees, light poles, mail boxes, and other fixed facilities. The effective width of the sidewalk is equal to the actual width minus the space taken up by various obstructions. Each obstruction's width is a function of its real width and shy distance. The effective width of a sidewalk along a given distance is determined by the minimum width along the distance under consideration. The following equation, and the information presented in Tables 2 (metric) and 3 (feet) can be used to estimate the effective sidewalk width.

$$W_{Effective} = W_{Total} - W_{Obstructions} \quad \text{Equation for Effective Width of Sidewalk}$$

The following procedures can be used to determine the optimal sidewalk width (17).

- Estimate the future pedestrian volume (in pedestrians per minute).
- Set a goal PLOS and select the appropriate flow rate from Table 2 or Table 3.
- Divide the pedestrian volume by the flow rate to determine the effective sidewalk width.
- Construct the sidewalk wide enough to accommodate the effective width plus any clearance distance from walls, trees, parking meters, and other obstacles.

The following example illustrates this concept. Assume the future pedestrian volume on a sidewalk will be 1350 pedestrians per 15-minute period or 90 pedestrians per minute, and that a PLOS of C is desired. The row in Table 2 or Table 3 for PLOS of C has a flow rate of 32.8 pedestrians per minute per meter or 10 pedestrians per minute per foot. The effective minimum

sidewalk width is determined by dividing the pedestrian volume by the flow rate. Using metric units, the following computation would be conducted:

$$\frac{90 \frac{\text{ped}}{\text{min}}}{32.8 \frac{\text{ped}}{\text{min} * \text{m}}} = \frac{90}{32.8} \text{m} = 2.75\text{m} (9\text{ft})$$

Table 2. Pedestrian Level of Service on Walkways (Metric)

Level of Service	Space (Square Meters/Pedestrian)	Expected Flows and Speeds		
		Average Speed, S (Meters/Minute)	Flow Rate, v (Pedestrian/Minute/Meters)	Volume/Capacity Ratio v/c
A	≥ 109.2	≥ 79.23	≤ 6.56	≤ 0.08
B	≥ 33.6	≥ 76.20	≤ 6.99	≤ 0.28
C	≥ 20.2	≥ 73.15	≤ 32.81	≤ 0.40
D	≥ 12.6	≥ 68.58	≤ 49.21	≤ 0.60
E	≥ 5	≥ 45.72	≤ 82.02	≤ 1.00
F	< 6	< 45.72	---- Variable ----	

*Average conditions for 15 minutes.
Source: (17).

Table 3. Pedestrian Level of Service on Walkways (Standard)

Level of Service	Space (Square Feet/Pedestrian)	Expected Flows and Speeds		
		Average Speed, S (Feet/Minute)	Flow Rate, v (Pedestrian/Minute/Feet)	Volume/Capacity Ratio v/c
A	≥ 130	≥ 260	≤ 2	≤ 0.08
B	≥ 40	≥ 250	≤ 7	≤ 0.28
C	≥ 24	≥ 240	≤ 10	≤ 0.40
D	≥ 15	> 225	≤ 15	≤ 0.60
E	≥ 6	≥ 150	≤ 25	≤ 1.00
F	< 6	< 150	---- Variable ----	

*Average conditions for 15 minutes.
Source: (17).

It should be noted that the effective sidewalk width of 2.75 m (9 feet) in this example must be increased to a total width by using the previous equation and the information provided in Table 4.

The following steps can be used to determine the PLOS of an existing facility:

- Determine the existing pedestrian traffic (in pedestrians per minute) and the effective sidewalk width (in meters) using the previous equation,
- Divide the effective width into the pedestrian volume to determine the flow rate,
- Use Table 2 or Table 3 to identify the PLOS.

For example, assume the existing pedestrian traffic is 1350 pedestrians per 15-minute period or 90 pedestrians per minute, the sidewalk total width is 3.97 m (13 feet), and the maximum obstruction width is 1.22 m (4 feet). The equation is used to determine an effective width of 2.75 m (9 feet) (3.97 m - 1.22 m or 13 feet - 4 feet). By dividing the pedestrian volume by the minimum effective sidewalk width, the pedestrian flow rate can be obtained. The following calculation completed this process.

$$\frac{90 \frac{ped}{min}}{2.75m} = \frac{90 \frac{ped}{min * m}}{2.75 \frac{ped}{min * m}} = 32.8 \frac{ped}{min * m}$$

Using the flow rate column in Table 2 or Table 3, it is determined that a flow rate of 32.8 pedestrians per minute meter or 10 pedestrians per minute per foot has an associated PLOS of C.

Table 4. Fixed Obstacle Width Adjustment Factors for Walkways

OBSTACLE	APPROXIMATE WIDTH PREEMPTED METERS (FT)**
STREET FURNITURE	
Light Poles	0.76 m to 1.1 m (2.5 ft to 3.5 ft)
Traffic Signal Poles and Boxes	0.91 m to 1.22 m (3.0 ft to 4.0 ft)
Fire Alarm Boxes	0.76 m to 1.1 m (2.5 ft to 3.5 ft)
Fire Hydrants	0.76 m to 0.91 m (2.5 ft to 3.0 ft)
Traffic Signs	0.61 m to 0.76 m (2.0 ft to 2.5 ft)
Parking Meters	0.61 m (2.0 ft)
Mail Boxes 0.52 m by 0.52 m (1.7 ft by 1.7 ft)	0.82 m to 0.98 m (2.7 ft to 3.2 ft)
Telephone Booths 0.82 m by 0.82 m (2.7 ft by 2.7 ft)	1.22 m (4.0 ft)
Waste Baskets	0.91 m (3.0 ft)
Benches	1.52 m (5.0 ft)
PUBLIC UNDERGROUND ACCESS	
Subway Stairs	1.68 m to 2.13 (5.5 ft to 7.0 ft)
Subway Ventilation Gratings (raised)	1.83 m (6.0 ft) -
Transformer Vault Ventilation Gratings (raised)	1.52 m (5.0 ft) +
LANDSCAPING	
Trees	0.61 m to 1.22 m (2.0 ft to 4.0 ft)
Planting Boxes	1.52 m (5.0 ft)
COMMERCIAL USES	
Newsstands	1.22 m to 3.96 m (4.0 ft to 13.0 ft)
Vending Stands	variable
Advertising Displays	variable
Store Displays	variable
Sidewalk Cafes (two rows of tables)	variable, try 2.13 m (7.0 ft)
BUILDING PROTRUSIONS	
Columns	0.76 m to 0.91 m (2.5 ft to 3.0 ft)
Stoops	0.61 m 1.83 m (2.0 ft to 6.0 ft)
Cellar Doors	1.52 m to 2.13 m (5.0 ft to 7.0 ft)
Standpipe Connections	0.3 m (1.0 ft)
Awning Poles	0.76 m (2.5 ft)
Truck Docks (trucks protruding)	variable
Garage Entrance/Exit	variable
Driveways	variable

* To account for the shy distance normally occurring between pedestrians and obstacles, an additional 0.3 m to 0.46 m (1.0 ft to 1.5 ft) must be added to the physical width of individual obstacles.

** Curb to edge of object or building face to edge of object.

Source: (17).

CHAPTER THREE—ROADWAY IMPROVEMENTS TO ACCOMMODATE BICYCLING

A number of improvements can be made to existing roadways to provide a safer and more comfortable riding environment for bicyclists. These same considerations can be incorporated into the design of new roadways. Providing extra space in existing general-purpose traffic lanes or developing separate bicycle lanes adjacent to the general-purpose traffic lanes represents two approaches that can be used to accommodate bicyclists. Further, addressing issues relating to pavement quality, utility grates, railroad crossings, intersections, bridges, and tunnels can all provide a safer and smoother operating environment for bicyclists.

This chapter provides a general overview of the design characteristics associated with incorporating bicycle facilities into new and existing roadways. It discusses typical bicycle and rider characteristics and design considerations for bicycle use of wide traffic lanes, separate bicycle lanes, and shoulders. Design features for intersections, bridges, underpasses, and railroad grade crossings are also outlined. Finally, improvements relating to pavement quality and other on-street obstacles are described.

TYPICAL BICYCLE AND RIDER DESIGN DIMENSIONS

The design process should consider the dimensions of a typical bicycle and rider. As illustrated in Figure 3, the width of a typical bicycle is .6 m (2 feet), the length is 1.8 meters (6 feet), and the height of a bicycle and rider is 2.5 m (8.5 feet). This information can be used in designing various types of bicycle facilities.

APPROACHES AND DESIGN CHARACTERISTICS

Three general approaches can be used to accommodate bicycles on roadways. The first is for bicycles and general traffic to share a wider outside travel lane. The second is to provide a separate bicycle lane adjacent to the general-purpose lane. A third approach is for bicyclists to ride on the shoulder of a roadway. By segregating motor vehicles and bicycles, the second approach provides the safest operating environment for all roadway users. The design of intersections, driveways, and other potential conflict points should be carefully considered when bicycles are segregated from motor vehicles. The general design characteristics associated with all three approaches are described in this section.

Sharing a Wide General-Purpose Lane

A standard general-purpose travel lane on an arterial street or roadway is normally 3.6 m (12 feet). One approach to accommodating bicycles on an existing or new roadway is to widen the outside or right-hand lane. A lane width of at least 4.2 m (14 feet) may be considered with this approach. Figures 4 through 6 provide examples of roadway cross sections that include wider lanes for bicyclists. The additional width provides space for motor vehicles to pass bicyclists without moving into the adjacent lane and improves the sight distance for all users.

TYPICAL BICYCLE AND RIDER DIMENSIONS	
CHARACTERISTICS	DIMENSIONS
Width	0.6 meters (2 feet) (handlebar width)
Length	1.8 meters (6 feet)
Height	2.5 meters (8.5 feet)
Vertical Pedal Clearance	0.15 meters (0.50 feet)

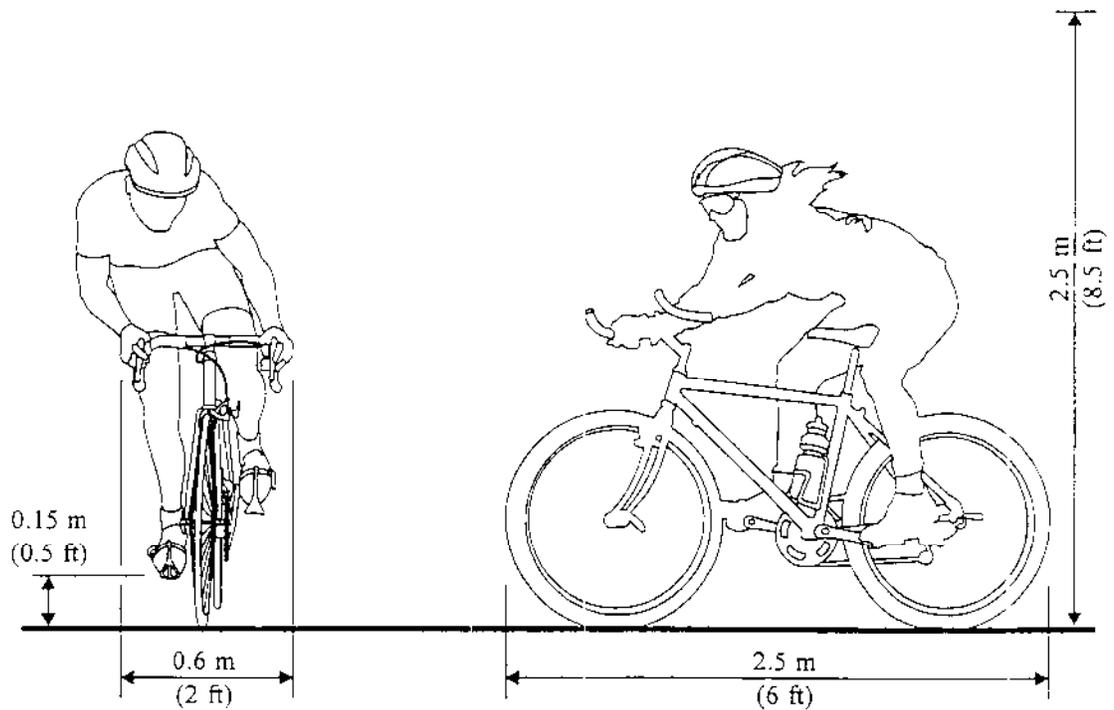


Figure 3. Typical Bicycle and Rider Dimensions

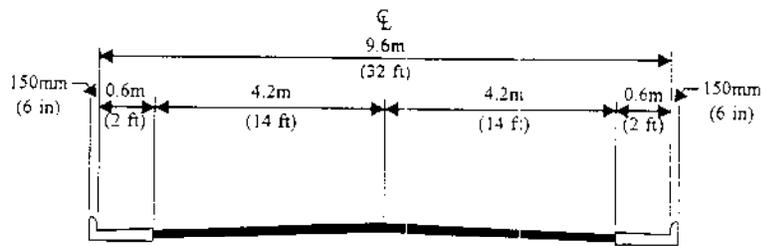


Figure 4. Example of Two-Lane Roadway with Wide Outside Lanes to Accommodate Bicycles

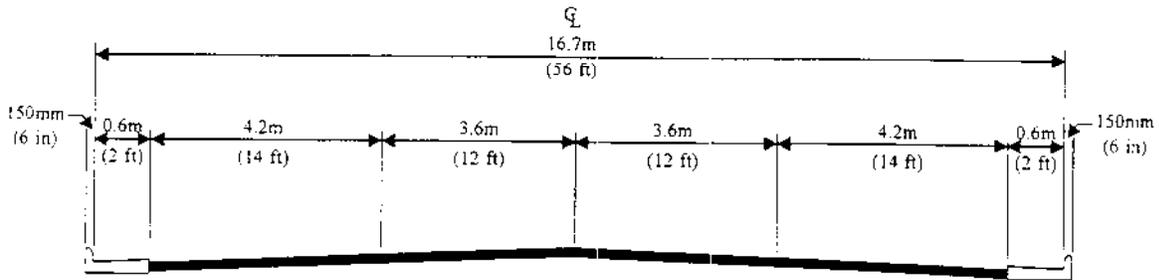


Figure 5. Example of Four-Lane Roadway with Wide Outside Lanes to Accommodate Bicycles

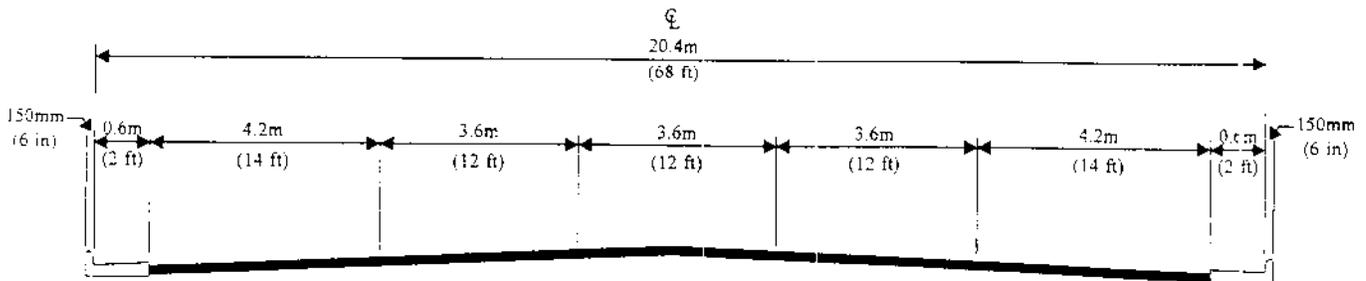


Figure 6. Example of Five-Lane Roadway with Wide Outside Lanes to Accommodate Bicycles

Consideration of wider lanes, in the range of 4.5 m (15 feet), may be appropriate in some instances. For example, wider outside lanes may be justified on some high speed roadways or on roads with large volumes of trucks. Extra width may also be needed if there are major obstructions along a roadway, as there is a natural tendency for bicyclists and motorists to move away from drainage grates, parked vehicles, or other features.

Wide outside lanes can be considered with new roadways and the retrofit or reconstruction of existing facilities. In the case where an existing roadway cannot be widened, consideration may be given to narrowing and restriping the inside lane or lanes and adding the extra width to the outside lane. In general, the width of inside lanes should not be reduced to less than 3.3 m (11 feet). In some cases, such as an existing four-lane divided road with low speeds and low vehicle volumes, it may be appropriate to consider restriping the roadway to a 4.2 m (14 feet) outside lane and 3 m (10 feet) inside lane. Figures 7 and 8 provide examples of modifying the cross section of an existing roadway to accommodate wider outside lanes.

Reducing the width of existing lanes should be evaluated carefully, however, as narrowing a lane from 3.6 m to 3.3 m (12 feet to 11 feet) can reduce the lane's capacity by up to five percent. Elements that should be considered in assessing the potential use of this approach include access controls, traffic volumes, level of service, and truck volumes. For example, roadways with truck volumes of greater than five percent of the total traffic may not be appropriate for this type of treatment.

Bicycle Lanes

A second approach to accommodating bicycle traffic along roadways is to provide a separate lane on the facility reserved exclusively or primarily for bicycles. The most appropriate roadways for bicycle lanes should be determined through the planning process described in the previous chapter. Bicycle lanes are located on the right side of a roadway, adjacent to the general-purpose lanes. There are at least three general approaches that may be used to design and operate bicycle lanes. As described next, these are bicycle lanes with no on-street parking, bicycle lanes with on-street parking lanes, and joint-use bicycle and parking lanes. In some cases this last alternative may also include joint use by buses or high-occupancy vehicles during some or all of the day.

Bicycle Lanes with No On-Street Parking. Figure 9 illustrates the cross section for a bike lane on an urban roadway with a curb and gutter, and Figure 10 shows the cross section for a bike lane on a rural roadway with a shoulder. In both cases, on-street parking is not permitted. As illustrated in Figures 9 and 10, the minimum suggested width for a bike lane is 1.2 m (4 feet). The urban cross section includes an additional .6 m (2 feet) for the curb and gutter. The rural roadway cross section includes a 1.2 m (4 feet) bike lane and a .6 m (2 feet) to 1.2 m (4 feet) shoulder. In both cases, a 150 mm (6 inch) solid white line is used to separate the bicycle lane from the general-purpose traffic lane.

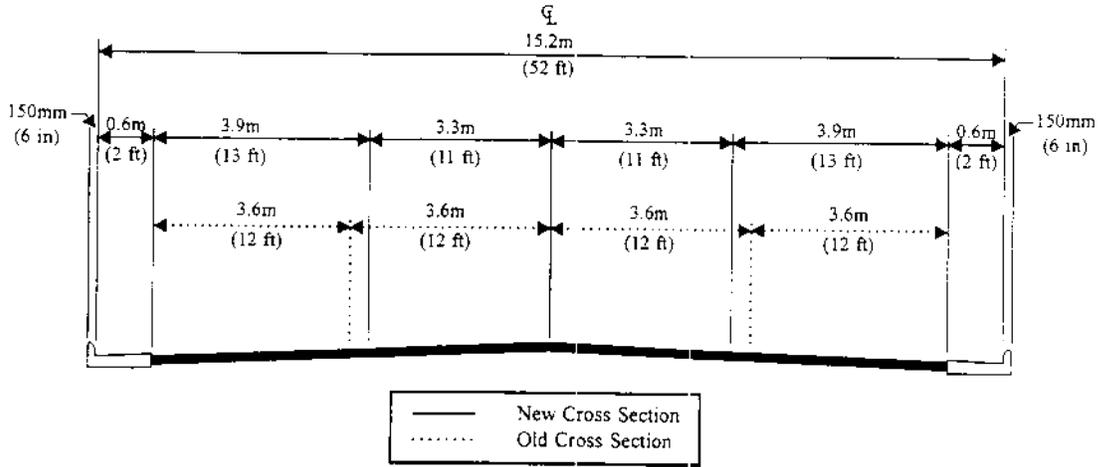


Figure 7. Example of a Four-Lane Roadway with Widened Outside Lanes to Accommodate Bicycles

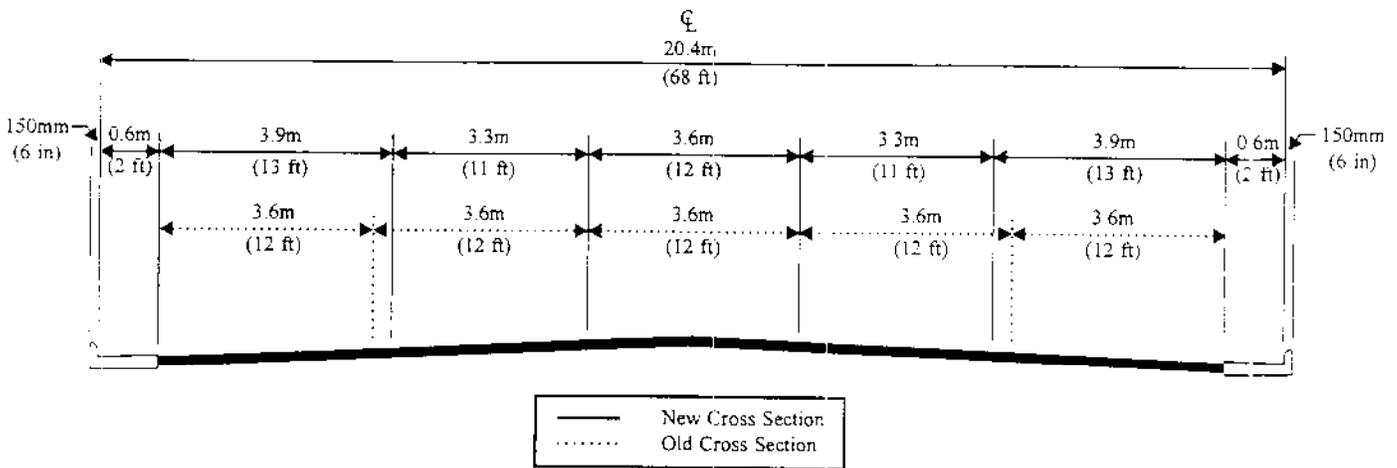


Figure 8. Example of Restriping a Five-Lane Roadway to Widen the Outside Lanes

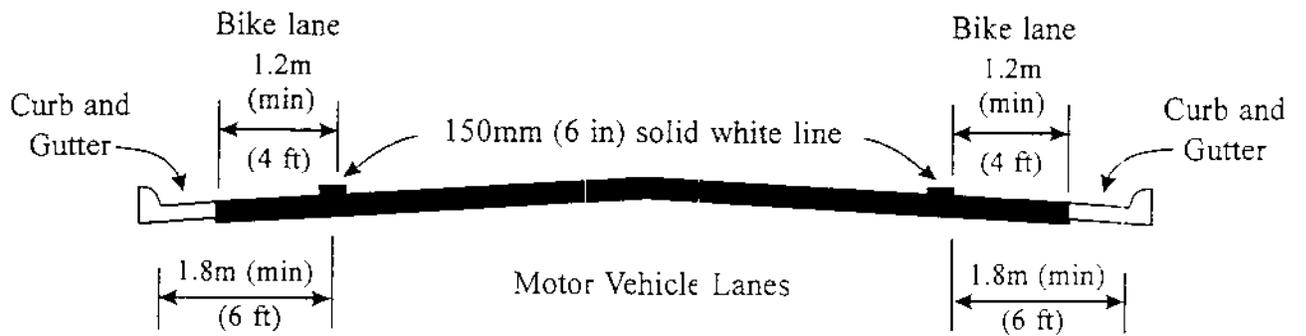


Figure 9. Examples of Bike Lanes on Urban Roadway

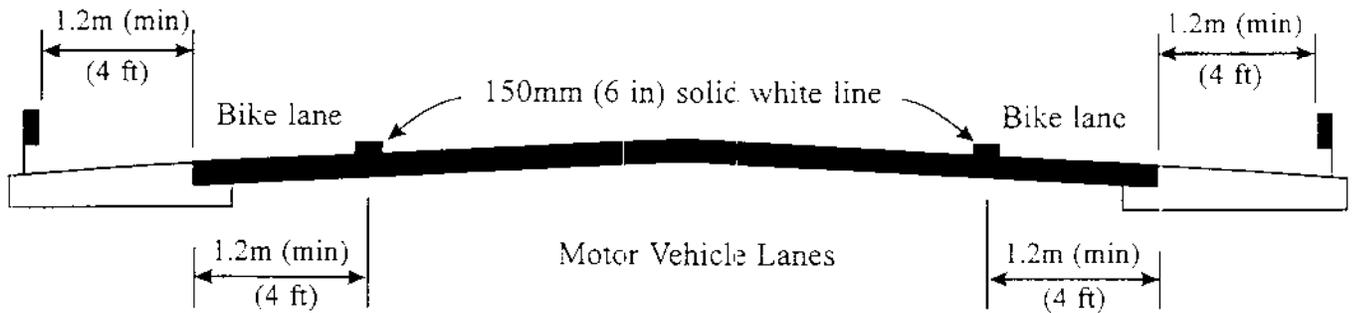


Figure 10. Examples of Bike Lanes on Rural Roadway

Bicycle Lanes with On-Street Parking. Figure 11 illustrates a cross section for a roadway with the bicycle lanes located between the general-purpose travel lanes and the on-street parking lanes. The bicycle lane is 1.2 m (4 feet) to 1.5 m (5 feet) wide and the parking lane and curb and gutter is 2.4 m (8 feet) to 3 m (10 feet) wide. The bicycle lane is separated from the general purpose lane by 150 mm (6 inch) solid white line. In addition, a 100 mm (4 inch) white line can be used to separate the bike lane from the parking lane.

Shared Bicycle and Parking Lanes. Figure 12 provides an example of a cross section with shared bicycle and parking lanes. A 3.6 m (12 feet) combined parking and bike lane, and curb and gutter, is shown in the example. A wider lane may be appropriate where the volume of on-street parking or delivery vehicles is high. This approach may be used in short segments where no other options are available. A variation on this alternative is the shared use of bus-only lanes by bicycles. These shared-use lanes are most commonly found in downtown areas where the curb lane is restricted for buses and bicycles for all or a portion of the day. Of the three alternatives, this approach is usually the least desirable due to potential conflicts between bicyclists and vehicles parking or making delivery stops.

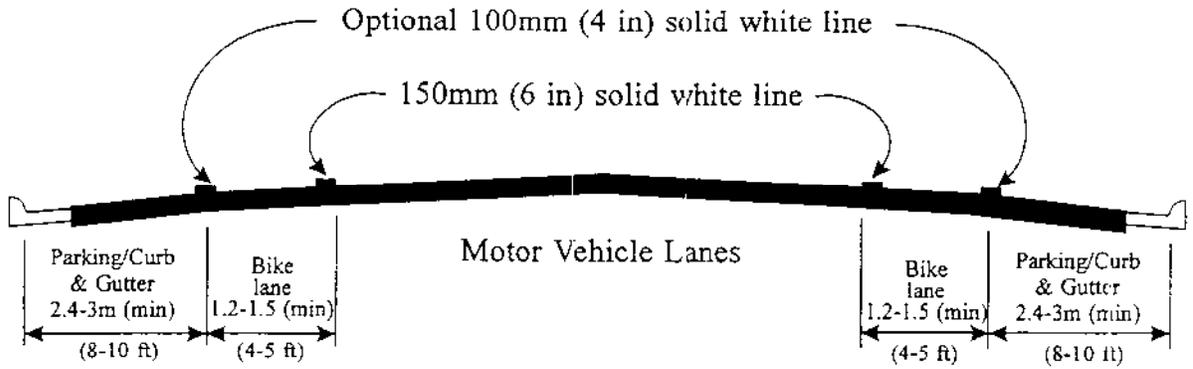
Shoulders

Shoulders may also be used in some areas for bicycles. In general, this approach is most appropriate for consideration in rural areas or on low-volume roadways. A shoulder width of at least 1.2 m (4 feet) should be considered if bicycle use is anticipated. Additional width is desirable, especially if motor vehicle speeds are above 60 km/h (35 mph) on the roadway, if there are high volumes of trucks and buses, or if other unique conditions exist. Figure 13 provides an example of a cross section with the shoulders designed for use by bicycles. As illustrated in Figure 13, special consideration should also be given to the clearance from the pavement edge to the plane of the foreslope of a ditch, guardrail, or roadside sign. Consideration should also be given to ensuring that the shoulder pavement quality is good.

INTERSECTIONS

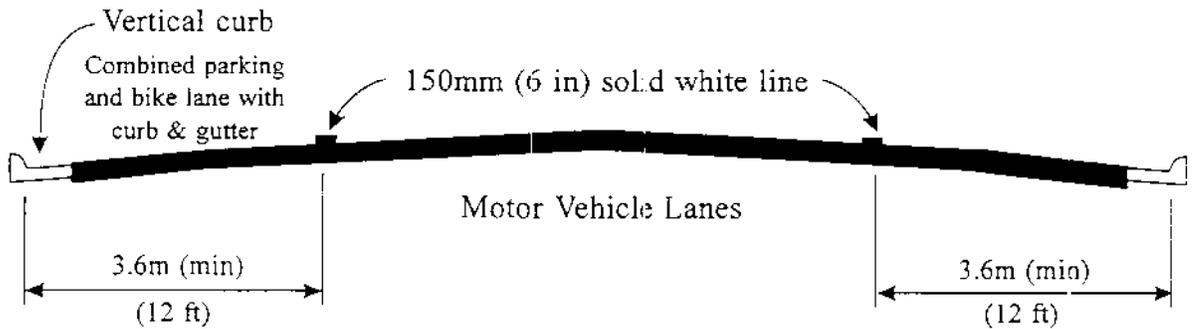
The design and operation of an intersection will be influenced by the type of bicycle treatment provided. Factors that may need to be considered include accommodating right and left turning movements for both motor vehicles and bicycles, signing and pavement marking, and signal timing and signal activation. Other issues may also need to be addressed based on local conditions.

Ensuring that motor vehicles and bicycles can make all allowed movements at an intersection safely and with a minimum of conflict is an important design consideration. Unless restrictions exist, these will include through, right turn, and left turn movements as illustrated in Figure 14. The roadway characteristics, the type of bicycle treatment, and the nature of the intersection will all influence the potential approaches. Maintaining a safe operating environment for bicyclists and motor vehicles at intersections is critical.



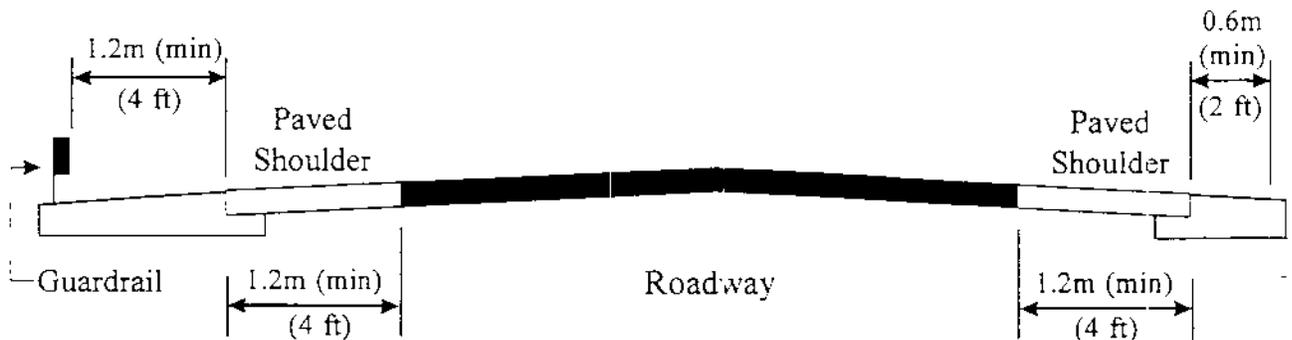
Source: (9).

Figure 11. Example of Bike Lane with On-Street Parking Lanes



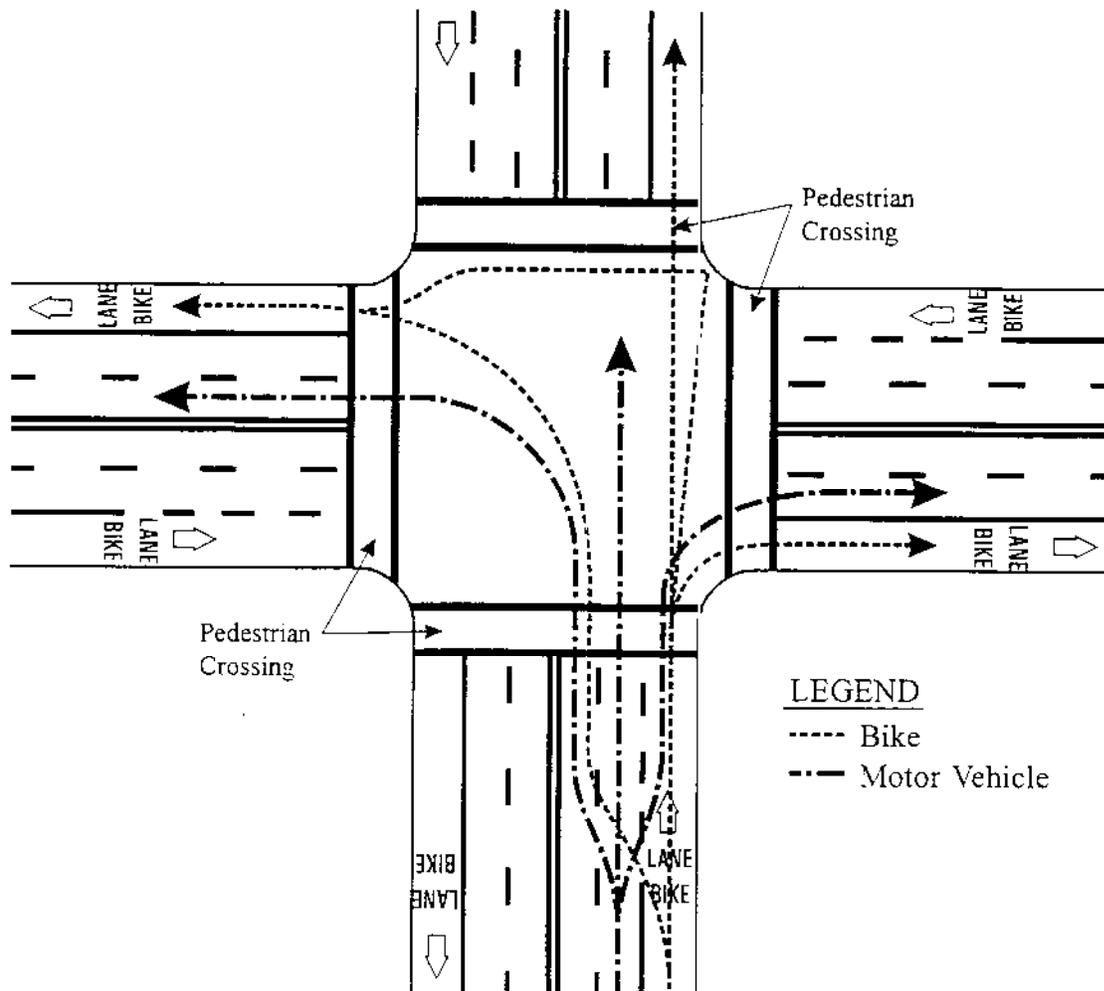
Source: (9).

Figure 12. Example of Shared Bike and On-Street Parking Lanes



Source: (9).

Figure 13. Example of Bike Use of Shoulders



Source: (5).

Figure 14. Examples of Motor Vehicle and Bicycle Movements at an Intersection

Figure 15 provides examples from the AASHTO *Guide for the Development of Bicycle Facilities* (11) on potential intersection design treatments with separate bicycle lanes. Avoiding potential conflicts between bicyclists traveling through an intersection and vehicles making right turns is often a key concern. The examples illustrated in Figure 14 can be used, along with signing, to help ensure the safe movement of bicycles and motor vehicles through an intersection. Part IV of the MUTCD provides guidance on bicycle signs and pavement markings.

The design and operation of an intersection may be further complicated with the use of near-side or far-side bus stops. The general concepts and designs shown in Figure 15 can be used in these situations. Extra consideration may be given to signing and pavement markings, however, to help communicate to all user groups.

A number of elements should be considered at signalized intersections that may be used by bicyclists. These include the location of the signal heads, the timing of the traffic signal cycle, and the activation of the signal. First, traffic signal heads should be located so that they are clearly visible to bicyclists who will usually be on the right side of the roadway.

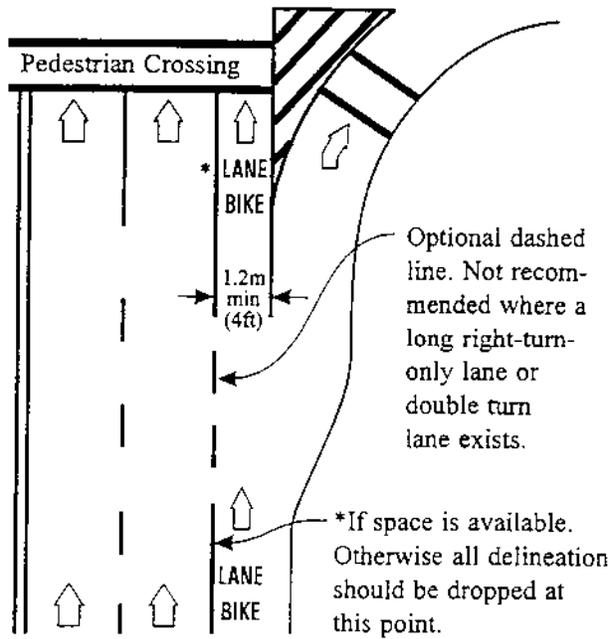
Second, the needs of bicyclists should also be considered when timing traffic signals. Adequate green time should be provided to allow bicycles to safely cross an intersection. A general bicycle speed of 16 km/h (10 mph) can be used to help determine the green time needed at an intersection.

Another issue that may need to be addressed at signalized intersections is the use of traffic-activated signals. At these intersections, loop detectors located in the pavement sense the presence of a vehicle and activate a change in the traffic light. If the loops do not record the presence of a vehicle, the traffic signal will not change, or will change based on a pre-set schedule which may involve lengthy red time. Bicyclists may encounter problems at intersections with traffic-activated signals. First, the loops must be able to detect the presence of a bicycle. Second, the loops must be placed in locations where bicyclists are likely to ride.

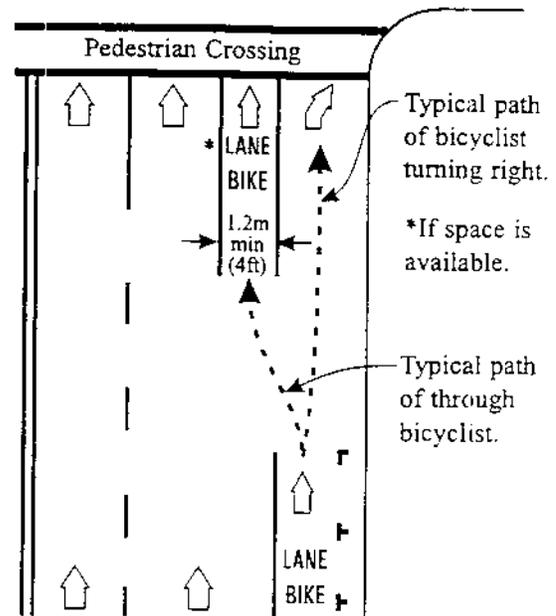
Matching the type of loop detector used to the specific situation at an intersection can help overcome these potential issues. The three general types of loop detectors—standard loop, quadruple loop, and diagonal quadruple loop—are illustrated in Figure 16. The characteristics, advantages, and disadvantages of each loop type are highlighted below.

Standard Loop Detectors. Standard loops are square or rectangular in shape. The outer boundary of these loops are the most sensitive for detecting the presence of a vehicle. As a result, standard loops may not provide the best detection for bicycles.

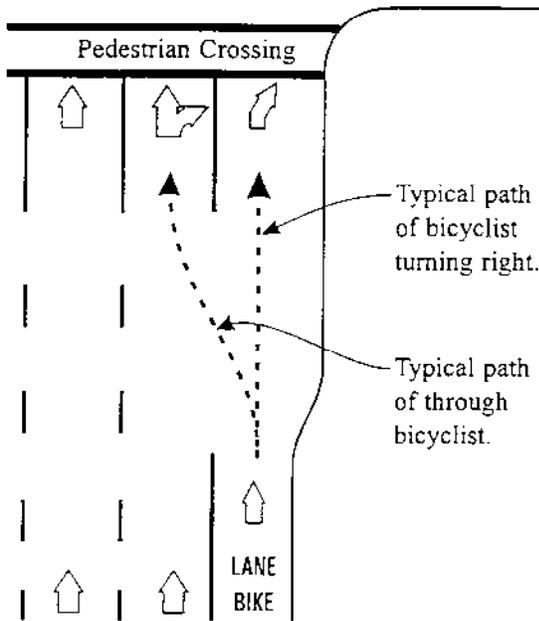
Quadruple Loop Detectors. These loop detectors are also sensitive on the outer boundary. Due to the configuration, however, the outer wire covers a larger area, including in the middle of the double loop. These loops may be appropriate for a bike lane where the path of the bicycle is predictable.



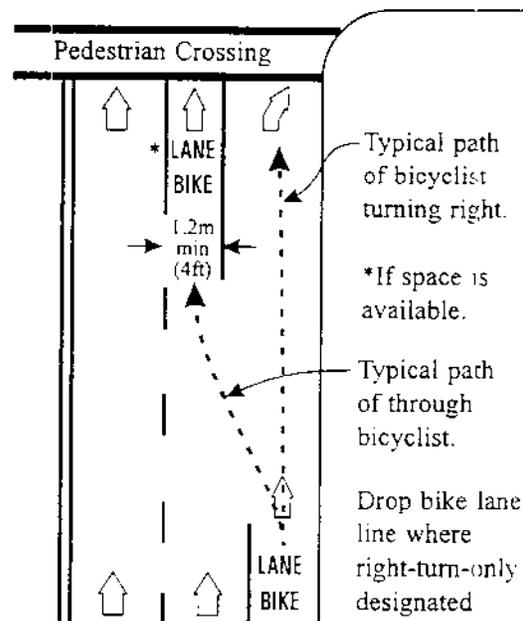
(1) Right-turn-only lane



(2) Parking area becomes right-turn-only lane



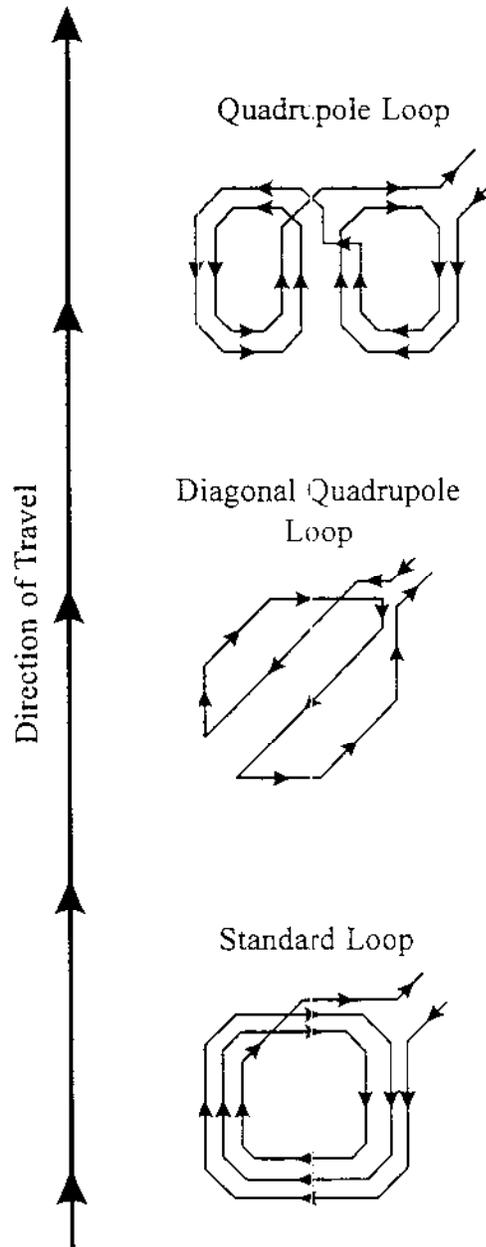
(3) Optional double right-turn-only lane



(4) Right lane becomes right-turn-only lane

Source: (11).

Figure 15. Examples of Intersection Treatments with Bike Lanes



Source: (9).

Figure 16. Examples of Traffic-Actuated Loop Detectors at Signalized Intersections

Diagonal Quadruple Loop. This style is sensitive over the whole loop. As a result, it may be the most appropriate style to use when bicycles share the roadway with other vehicles.

SIGNING AND PAVEMENT MARKINGS

Part IX of the MUTCD addresses the use of bicycle related signs and pavement markings on roadways. The MUTCD identifies the three purposes for bicycle signing. These are regulating bicycle use, directing bicyclists along pre-established routes, and warning bicyclists of unexpected conditions. The MUTCD provides guidance on the placement of bicycle related signing, the design and color of various signs, and the messages or content of each sign. Examples of bicycle signs from the MUTCD are shown in Figure 17. Part IV of the MUTCD should be referenced for the proper signing to use in various situations.

STRUCTURES

Special consideration may need to be given to bridges, tunnels, underpasses, and other structures located along a roadway used by bicyclists. Structures that may need modification should be identified, examined, and evaluated as part of the planning process described in Chapter Two. If a bridge, tunnel, or other structure is identified as a key element of a bicycle network, the need for possible modifications can then be examined and improvements can be programmed. Since changing the design of these structures may be expensive, consideration may also be given to alternative bicycle routes. This section highlights the design features associated with bicycle use of bridges and tunnels or underpasses.

Bridges

The four features usually considered with bicycle use of bridges are the deck width, the approach, the surface, and possible static obstructions. Each of these elements is briefly discussed next, and potential approaches to accommodate bicycles are outlined.

Bridge Deck Width. The width of the bridge deck, along with the volume and the speed of traffic, will influence the type of accommodations that can be made for bicycles. If adequate space is available, the bicycle treatment provided on the adjacent roadway—wide lane, bike lane, or shoulder—may continue on the bridge. If the deck width is narrower than the roadway, however, an alternate treatment may be needed. For example, a bike lane may be provided on a roadway but a shared wide outside lane may be used on a bridge due to deck width limitations. As discussed next, in these cases, transition zones should be used for bicycles approaching and leaving a bridge.

Approach. Consideration should be given to the approaches bicycles will use to enter and leave a bridge. A transition area of some 30 m (100 feet) can be provided on both sides of a bridge, if needed, to help bicyclists negotiate any changes. This transition area is especially important if a different treatment is used for bicycles on the bridge.

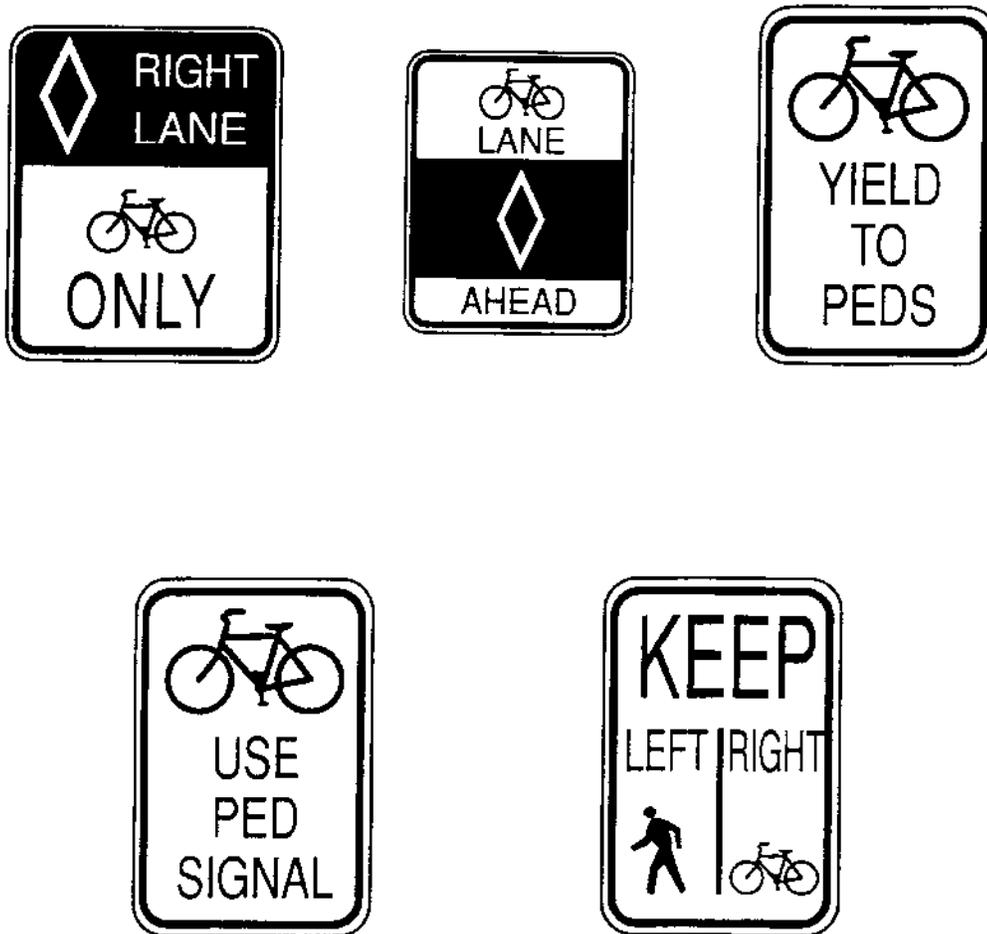


Figure 17. Examples of Bicycle Signs from MUTCD

Surface Conditions. Consideration should be given to the surface conditions of bridges that will be used by bicycles. Steel decking on draw or swing bridges, expansion joints, and other unique features may all pose potential hazards to bicyclists. Appropriate measures, such as rubberized joint fillers and other techniques, can be used to address specific problems.

Static Obstructions. These may include guardrails on bridge approaches, as well as bridge railings and other special features. The use of railings and guardrails should follow the AASHTO, FHWA, and TxDOT guidelines. As a general guide to provide adequate protection to bicyclists, the height of a railing should be at least 1,372 mm (54 inches), as measured from the riding surface to the top of the rail.

Tunnels and Underpasses

Existing tunnels and underpasses may also pose special challenges for accommodating bicycles. The use of these facilities versus alternate routes for bicycles should be examined in the planning process. In most cases, tunnels or underpasses on heavily traveled high speed roadways may not be the best environment for bicycles, and alternate routes should be used. Issues that may need to be considered if a tunnel or an underpass is to be used by bicyclists include available width, approach, surface quality, lighting, and ventilation. Each of these elements is described next.

Tunnel Width. The width of the tunnel or underpass will influence if and how bicycles can be accommodated. Like bridges, the same treatment used on the adjoining roadway should be used in the tunnel whenever possible. If the same treatment cannot be accommodated, the best alternative should be used.

Approach. Similar to bridges, consideration should be given to the approach bicyclists will use to enter and leave a tunnel or underpass. A transition zone of approximately 30 m (100 feet) should be provided on both sides of a tunnel or underpass. A transition zone may be especially important if a different bicycle treatment is used within the facility. Providing a transition zone will also be important on the climbing side of a tunnel located below the roadway grade to provide bicycles with space to regain normal cycling speed.

Surface Quality. Like all bicycle facilities, consideration should be given to ensuring that the tunnel surface provides a safe and comfortable ride. Debris, which may cause problems for bicycles is often more of a problem in tunnels than on a roadway. Regular sweeping and maintenance can address this possible problem.

Lighting. Lighting needs should also be considered in tunnels and underpasses that will be used by bicyclists. The length of the facility will influence the type and the extent of lighting needed. In some areas, manually activated lights may be considered for use in underpasses and tunnels.

Ventilation. Depending on the length of the tunnel and the traffic volume, consideration may need to be given to air quality concerns. Bicyclists will spend a longer time in the

tunnel than motor vehicles and will be more exposed to exhaust fumes. As a result, ensuring that adequate ventilation is provided may be important in some facilities.

ROADWAY SURFACE IMPROVEMENTS

Existing conditions along a roadway may cause safety hazards to bicyclists or may result in an unpleasant riding environment. Uneven or rough pavement, drainage grates and utility covers, railroad grade crossings, and on-street parking represent just a few conditions that may negatively impact bicyclists. This section examines possible improvements that can be made to address these issues.

Pavement Quality

Irregularities in the pavement surface, potholes, and poor pavement quality can cause both an unpleasant ride for bicyclists and safety concerns. For example, uneven pavement may increase conflicts between bicycles and motor vehicles. Further, bumpy roadways provide an uncomfortable riding environment for bicyclists. As a result, consideration should be given to ensuring that the bicycle portion of the roadway has a smooth surface.

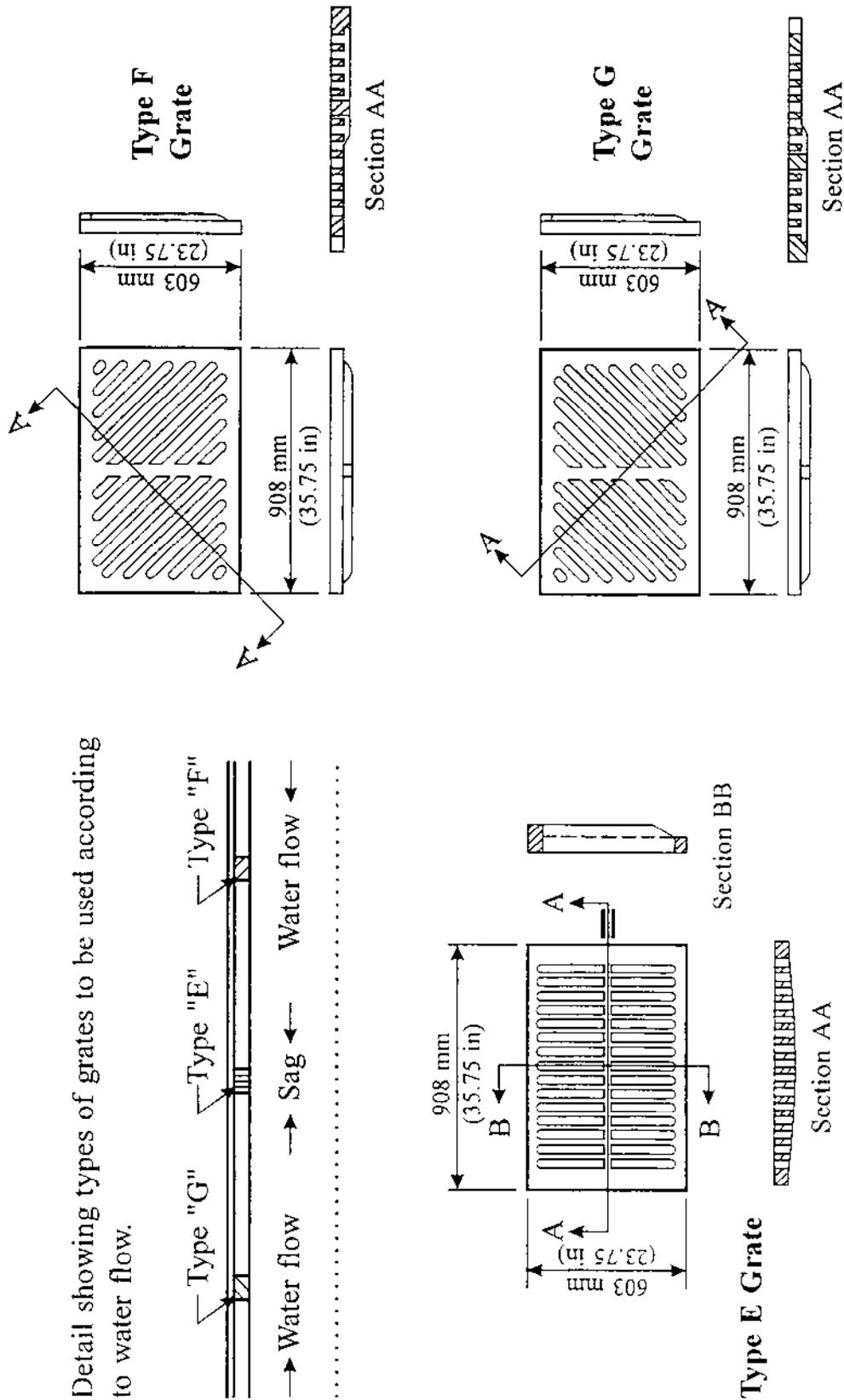
The same pavement standards used for the traffic lanes should also be used for the bicycle lane or the bicycle portion of the roadway. The surface for bicycles should be smooth and free of potholes or ruts. Consideration should also be given to providing a uniform roadway edge treatment as well as feathering the asphalt to ensure a smoother transition between pavements if the roadway is being repaved. Further, rumble strips may be hazardous to bicycles and care should be taken when locating these along routes used by bicyclists.

Drainage Grates and Utility Covers

Drainage grates and utility covers are typically found along roadways, especially in urban areas. Although these elements serve important functions, they can be hazardous to bicyclists. Improvements can be made, however, to address many of these issues. As discussed next, possible approaches include replacing hazardous covers, providing space for bicyclists to maneuver around the grates, clearly marking the hazard, and resurfacing.

Replace Drainage Grates and Utility Covers. One approach is to replace unsafe drainage grates or utility covers. Since the parallel bar drainage covers are the most hazardous, these should be considered for replacement first. Figure 18 illustrates three bicycle safe drainage grates that have been approved for use in North Carolina. The TxDOT Standard Sheets provide more information on grate design considerations.

Providing Additional Space for Bicyclists. A second option is to examine the potential to provide additional space for bicyclists to maneuver around a grate or other hazard. Although this approach may not be possible in many situations, examining ways to provide bicyclists with extra room to bypass a problem area may be possible in some cases.



Source: (9).

Figure 18. Examples of Bicycle Safe Drainage Grates

Clearly Marking the Hazard. Another approach is to identify a hazardous grate with a pavement marking. The MUTCD provides examples of marking that may be used in this situation. This approach has limitations, however, as a bicyclist may not see the pavement marking, especially during dawn and dusk time periods, or may not be able to respond fast enough to avoid the grate. Providing some type of marking or signing is better than not doing anything, however, and may be used as an interim step while other, more permanent measures are being taken.

Resurfacing. Special attention should be given when roadways used by bicycles are being repaved to avoid hazards such as projections above the pavement surface, which may occur around grates. Consideration should be given to ensuring that all grates, curb inlets, and other elements are brought to grade.

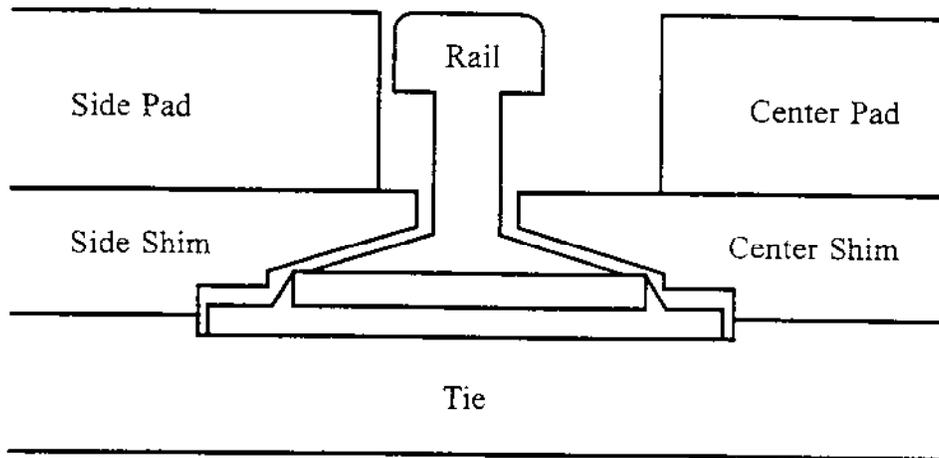
Railroad Grade Crossings

Railroad grade crossings represent another potential hazard for bicyclists. The rails may cause a major change in the level of the travel surface resulting in wheel damage or even causing a bicyclist to fall. In addition, if the tracks cross the roadway at less than 45 degrees, the front wheel of a bicycle may be caught by the rail or trapped in the flange way, which is the space between the rail and the rail bed, causing an accident. As highlighted below, possible approaches to address these concerns include rubberized grade crossing material, flange way fillers, widening the approach lane, providing extra signing, and removing tracks of abandoned railroads.

Rubberized Railroad Crossing Material. A rubberized crossing may be installed to provide a smoother ride across a railroad track for bicycles and motor vehicles. As illustrated in Figure 19, this technique usually consists of a concrete base with a rubberized surface. Rubberized crossings are relatively expensive to install but can have significant long-term savings in maintenance costs. Variations of this approach can also be used. For example, Florida and parts of Texas use concrete instead of rubber.

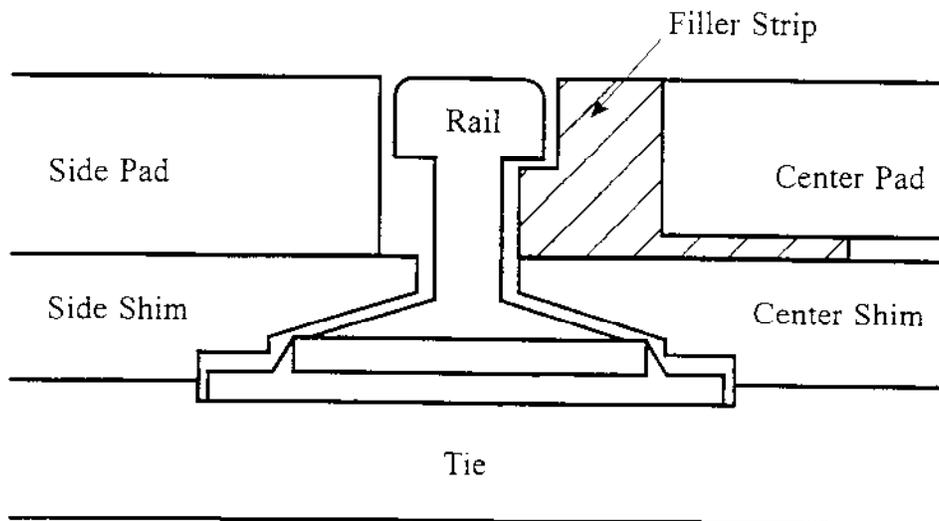
Flange Way Fillers. Commercial flange way fillers are available and can be used to fill the gap between the rail bed and the rail. An example of a flange way filler is illustrated in Figure 20. The flange way fill compresses when the wheel of a train rolls over. Flange way fillers may be appropriate to consider on lightly traveled and low speed railroad tracks. They should not be used with high-speed rail lines, as the filler will not compress fast enough and the train may derail.

Widening Bicycle Approach. Another alternative is to widen or reorient the bicycle approach to a railroad crossing to ensure that bicycles cross at approximately 90 degrees. Figure 21 provides an example from the Arizona bicycle guidelines, which suggests an additional 1.8 m (6 feet) to 2.4 m (8 feet) of right-of-way may be needed if this technique is used.



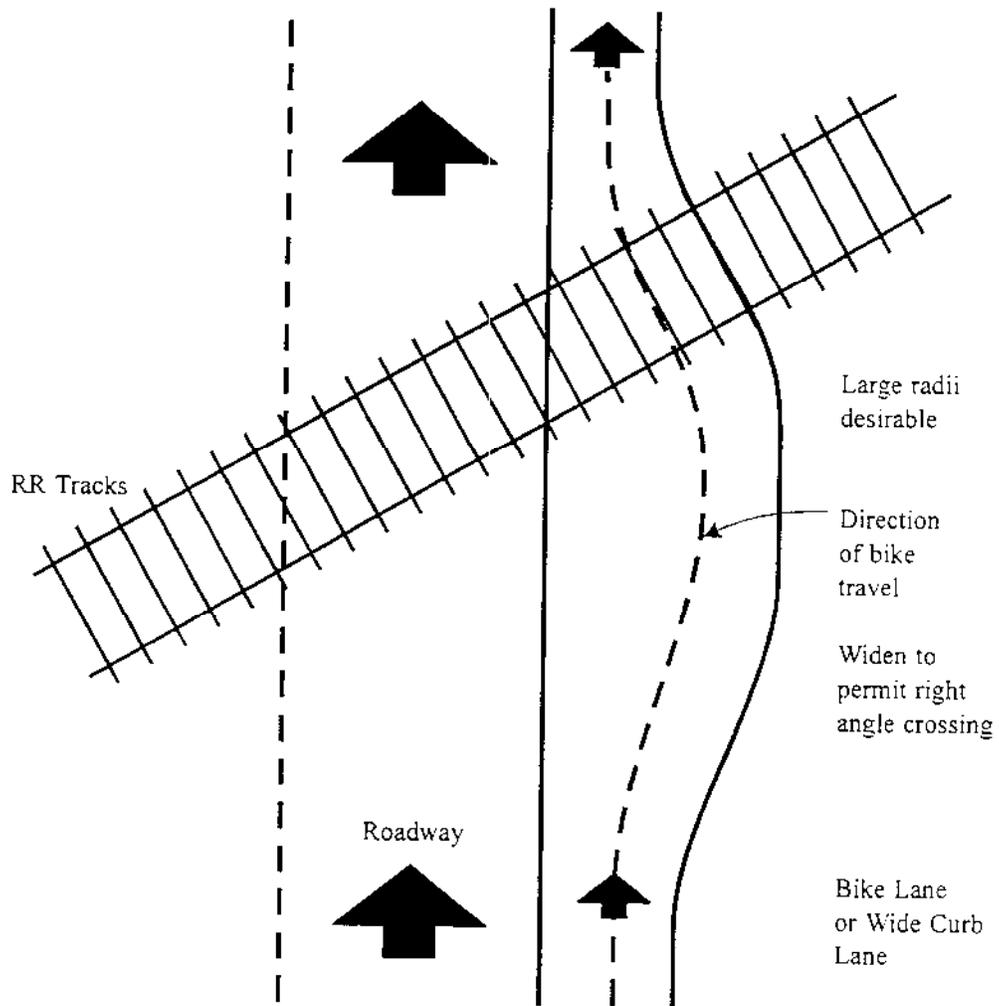
Source: (9).

Figure 19. Example of Rubberized Railroad Grade Crossing Material



Source: (9).

Figure 20. Example of Railroad Grade Crossing Flange Way Filler



Source: (5).

Figure 21. Example of Widening and Reorienting Bicycle Approach at Railroad Crossing

Signs and Pavement Markings. Signs and pavement markings can also be used to warn bicyclists of an upcoming railroad track. This technique may be used if no other approach is possible or it can be used in combination with other techniques. Although the MUTCD does not contain an approved sign for this specific situation, a W11-1 warning sign with an appropriate message may be used. Examples of possible messages include *Bikes Cross Track at Right Angle*, *Railroad Crossing Ahead*, or *Uneven Railroad Tracks Ahead*.

Removing Tracks. If the rail lines have been abandoned, removing the rails at a crossing may be an appropriate alternative to consider. This approach is obviously not viable if there is a good chance that the lines will be used again in the near future. Removing the rails only at the crossing, however, provides flexibility should service be restarted in the future.

MAINTENANCE

Maintaining the bicycle facilities described in this chapter should be part of the normal operation and maintenance of the roadway. As noted previously, TxDOT, cities, counties, and towns all have responsibilities for roadways in the state. Adequate maintenance of bicycle facilities on roadways is critical to ensuring a safe, comfortable, and convenient environment for bicyclists and motor vehicles. Regular sweeping is important to keep wide lanes, bicycle lanes, and shoulders clear of debris. Repairing potholes or other pavement problems should also be given a high priority on heavily used bicycle facilities. Thus, although the bicycle features on a roadway should be part of the regular maintenance program, extra attention may be appropriate to ensure a clean and smooth pavement for bicyclists. Attention should also be given to ensuring that signs and pavement markings are adequately maintained and visible to all user groups.

CHAPTER FOUR—SEPARATE BICYCLE PATHS AND MULTI-USE TRAILS

Rather than including a bicycle lane within a roadway right-of-way, a second approach is to provide a separate bicycle path or multi-use trail. These facilities may be oriented toward a variety of groups and trip purposes. For example, a path may be located adjacent to a roadway, serving both commuter and recreational bicycling trips, or a multi-use trail may be located in a park or rural area serving recreational activities. User groups may include bicyclists, walkers, joggers, and rollerskaters.

Although the exact design treatments used with bicycle paths and multi-use trails will vary depending on the location and the orientation of the facility, a number of common elements can be identified. The design features commonly associated with the various types of bicycle and multi-use paths and trails are presented in this chapter.

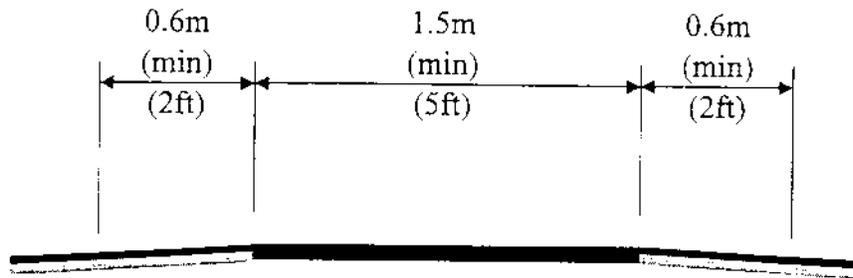
GENERAL DESIGN CONSIDERATIONS

Bicycle paths and multi-use trails are usually located in a separate right-of-way. Bicycle or multi-use paths may be located adjacent to a roadway, on an abandoned railroad right-of-way, in a park, or in a neighborhood area. Although there are many similarities between designing a roadway for motor vehicles and designing a pathway for bicycles, pedestrians, and other users, there are also numerous differences.

The design process must consider bicycle operating characteristics and the various users of a facility. Paths and trails intended for multiple user groups—such as bicycles, joggers, walkers, and rollerskaters—should be designed with the needs of each group in mind. Conflicts can emerge among these groups if separate paths or portions of a trail are not provided for various uses. As a result, key criteria in the design process are addressing the needs of bicyclists, which will be the fastest user group, and separating the various user groups to avoid potential conflicts. The information provided in this section can be used to assist in designing bicycle and multi-use paths and trails.

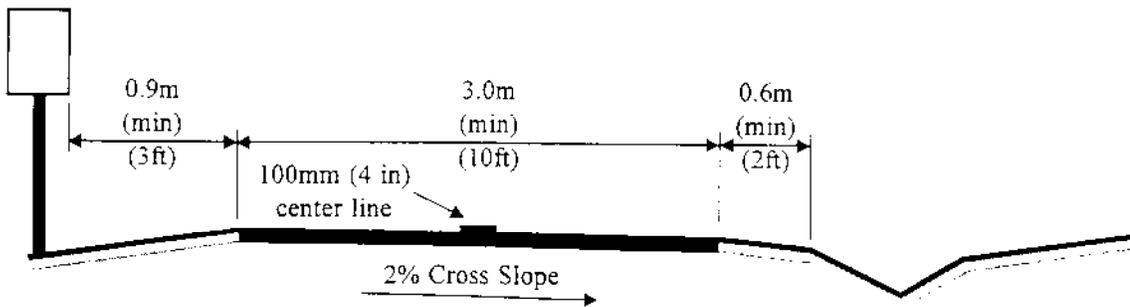
Facility Width

The width of a bicycle or multi-use path or trail should be matched to the intended user groups, whether it is a one-way or two-way facility, and available right-of-way. The suggested minimum paved width for a two-directional bicycle path is 3 m (10 feet) to allow bicycles to pass safely. This width can also accommodate low volumes of mixed user groups. Wider facilities will be needed if a large number of bicycles, walkers, joggers, and rollerskaters will be using the facility. Consideration may also be given to providing access for maintenance vehicles. Figures 22 through 25 provide examples of cross sections highlighting different path widths to meet the needs of different user groups. These examples can be used to help match the best design with the characteristics of a specific project.



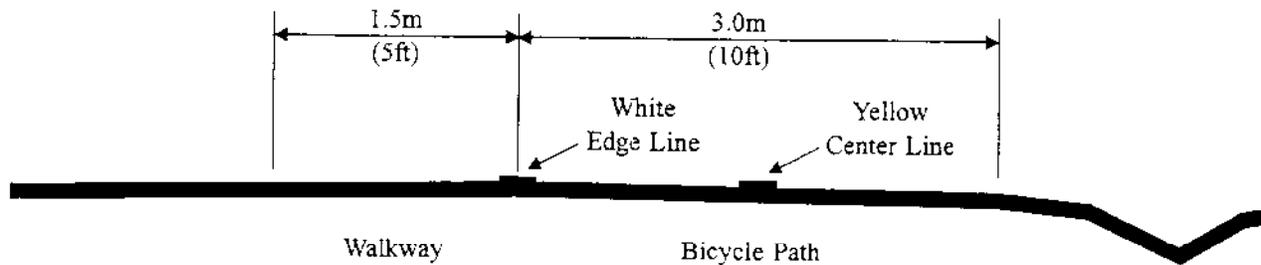
Source: (9).

Figure 22. Example of One-Way Bicycle or Multi-use Path



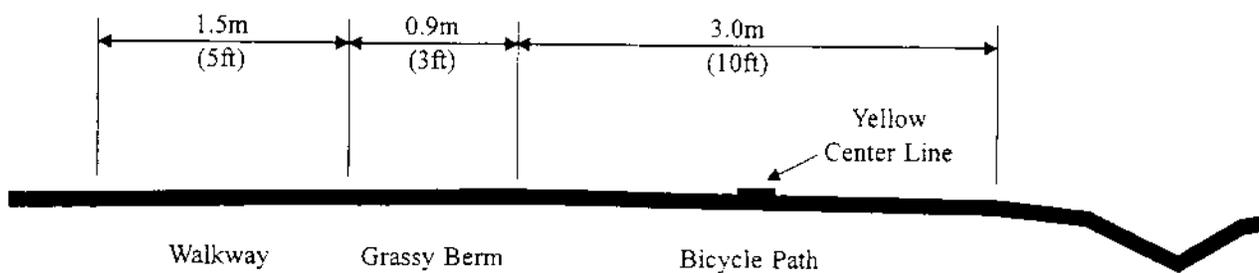
Source: (9).

Figure 23. Example of Two-Way Bicycle or Multi-use Path



Source: (9).

Figure 24. Example of Two-Way Multi-use Trail with Separate Bicycle and Pedestrian Paths



Source: (9).

Figure 25. Example of Two-Way Multi-use Trail with Bicycle and Pedestrian Paths Separated by Berm

Horizontal Clearances

Consideration should be given to the horizontal clearances associated with a bicycle or multi-use path. A graded area of .6 m (2 feet) to .9 m (3 feet) on both sides of the pathway is suggested to provide clearance from trees, shrubs, fences, and other lateral obstructions. Wider separations should be considered for safety reasons if the path is located next to a ditch, river, or other significant depression. In these cases, a vertical clearance of at least 1.5 m (5 feet) and some type of fencing or safety rail may be appropriate. Examples of these types of design treatments used in North Carolina are shown in Figure 26.

A bicycle or multi-use path should also be adequately separated from adjacent roadways. If the distance between the roadway and a path is less than 1.5 m (5 feet), consideration should be given to providing some type of positive barrier. These dividers, which should generally be at least 1.35 m (54 inches) high, help delineate the roadway and the bike path, providing a safer environment for users of both facilities.

Vertical Clearances

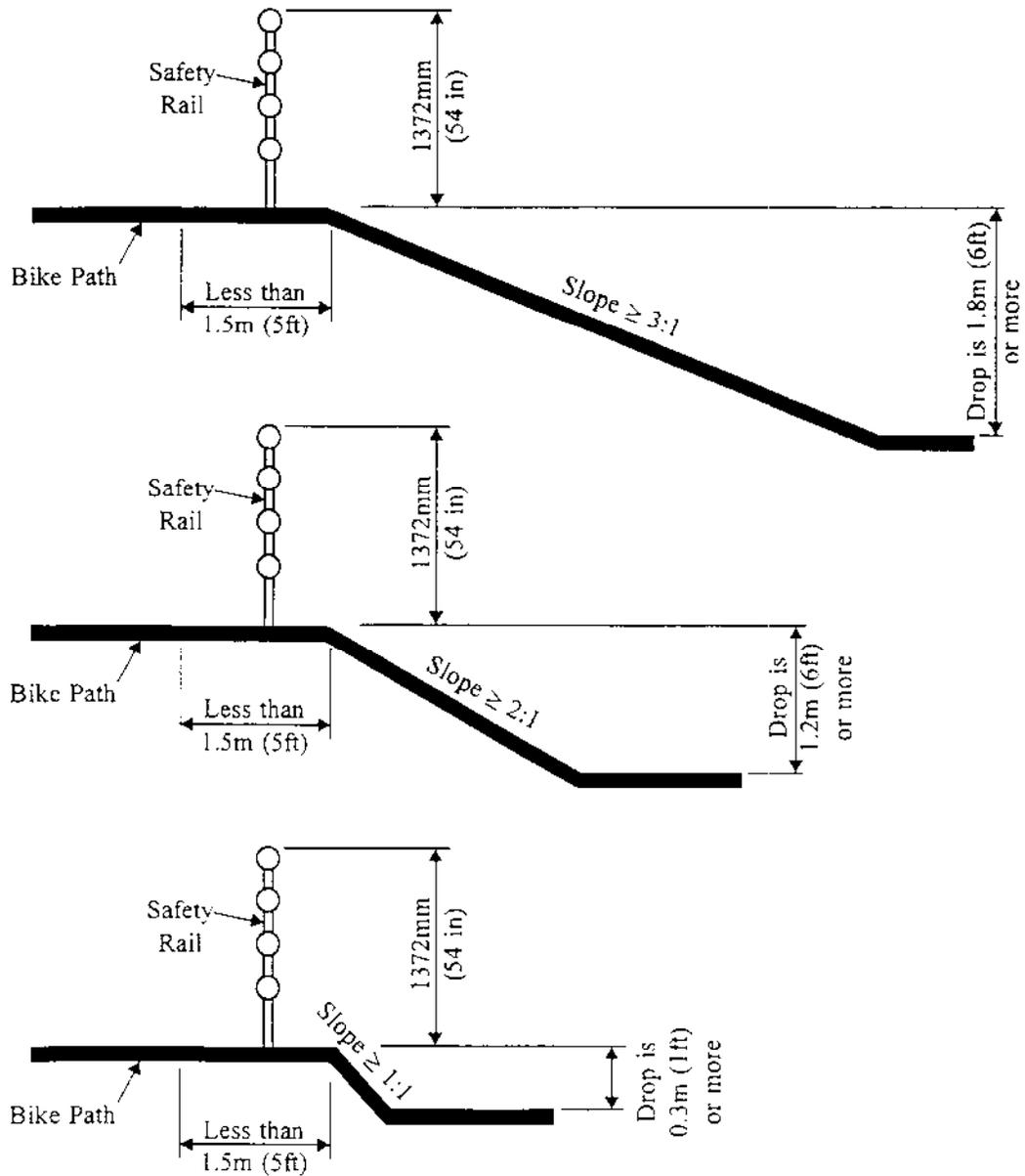
A vertical clearance of at least 2.4 m (8 feet) is suggested with bicycle paths. This minimum provides enough space for a bicycle and rider to travel safely under tree limbs or other overhead obstruction. A vertical clearance of 3 m (10 feet) may be needed if maintenance vehicles will access the facility. The 3 m (10 feet) vertical clearance is also appropriate for tunnels and underpasses.

Design Speeds

The speed bicycles will be traveling should be considered in the design process. The speed of bicycles using a facility will depend on a number of factors. These include the trip purpose, the type and condition of the bicycle, the physical condition of the bicyclist, the presence of other traffic, wind and weather conditions, and the condition of the path. Although the speed of the fastest anticipated bicyclists should be considered in the design process, a design speed of 35 km/h (20 mph) can be used as a general guideline for paved paths. A lower design speed, in the 25 km/h (15 mph) may be appropriate on unpaved paths, where riding speeds tend to be lower. On the other hand, a higher design speed, in the range of 50 km/h (30 mph) can be used when the grade exceeds four percent or in areas with strong prevailing tail winds.

Horizontal Alignment and Superelevation

The horizontal alignment of the facility should be designed to ensure that curves can be safely negotiated by all levels of bicyclists. The radius of curvature should be established based on the needs of a novice rider. The radius of curvature is a function of the superelevation rate of the surface, the coefficient of friction between the tires of a bicycle and the surface, the speed of the bicycle, and the amount of lean of the bicyclists. Since more advanced bicyclists can handle more lean, they can negotiate tighter curves. On the other hand, novice riders may have difficulty with sharper curves. As a result, the design of these facilities should meet the needs of less experienced riders.



Source: (9).

Figure 26. Examples of Safety Railings Used with Bicycle Paths in North Carolina

In general, the superelevation rate for a bicycle path or multi-use trail will range from +2 percent to +2.5 percent. A +2 percent superelevation is needed to promote adequate drainage, while any level above +5 percent may provide problems for slower, less experienced riders.

The following formula can be used to calculate the minimum design radius of curvature for a bicycle path.

$$R_{\min} = \frac{V^2}{15(e+f)} \qquad R_{\min} = \frac{V^2}{127\left(\frac{e_{\max}}{100} + f_{\max}\right)}$$

Where:

R_{\min} = Min. Radius of curvature (ft)
 V = Design speed (mph)
 e = Rate of superelevation (%)
 f = Coefficient of friction

R_{\min} = Min. Radius of curvature (m)
 V = Design speed (km/h)
 e_{\max} = Max. Rate of superelevation
 f_{\max} = Max. Coefficient of friction

The coefficient of friction for a bicycle path is a function of bicycle speed, surface type and condition, and bicycle tire type and condition. Weather conditions, including wet or dry pavement, will also influence the coefficient of friction. North Carolina has identified the friction factor and design radius for various bicycle speeds based on highway and bicycle facility design experience. These values, which are based on a superelevation rate (e) of +2 percent, are shown in Table 5. For unpaved bicycle facilities, the North Carolina guidelines suggest reducing the friction factors by 50 percent for safety reasons.

Problems may emerge with substandard curves on existing bicycle paths or with right-of-way limitations that may result in similar concerns on new facilities. Two general approaches can be used to deal with substandard curves. First, signs and pavement markings can be used in accordance with the MUTCD to warn approaching bicyclists. Second, widening the pavement on either the inside or the outside of the curve can help provide additional areas in which to negotiate the curve. Figure 27 illustrates the use of this approach in Washington State.

Table 5. Design Radii Used in North Carolina for Paved Bicycle Paths

Design Speed -V kph (mph)	(e= +2%) Friction Factor -f	Design Radius -R m (ft)
30 (20)	0=27	30 (95)
40 (25)	0=25	50 (155)
50 (30)	0=22	80 (250)
60 (35)	0=19	120 (390)
65 (40)	0=17	175 (565)

Source: (14).

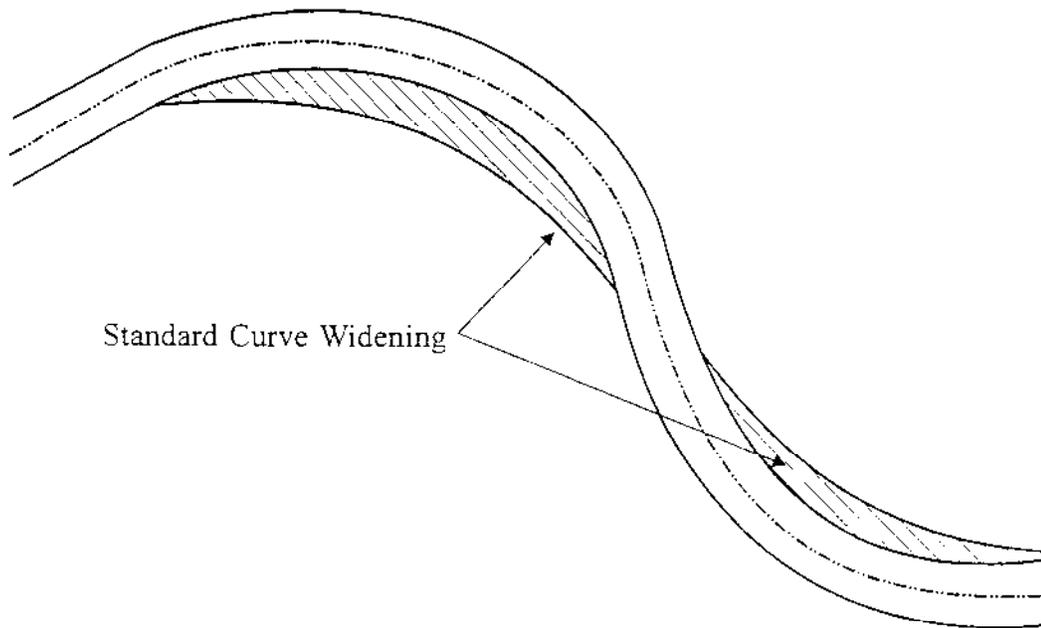
Grades

Most bicycle facilities, other than those for off-road mountain bikes, are intended to provide a level ride. As a result, steep grades should be avoided with bicycle paths and multi-use facilities for a number of reasons. First, many cyclists may not be able to ride up steep inclines. Second, bicyclists may obtain too high a speed on steep downhill grades. Both situations pose potential safety problems for bicyclists and for other trail users. As a result, grades of more than two percent are not suggested. Special considerations should be given to design features if grades of three to five percent will be encountered by bicyclists.

Sight Distance

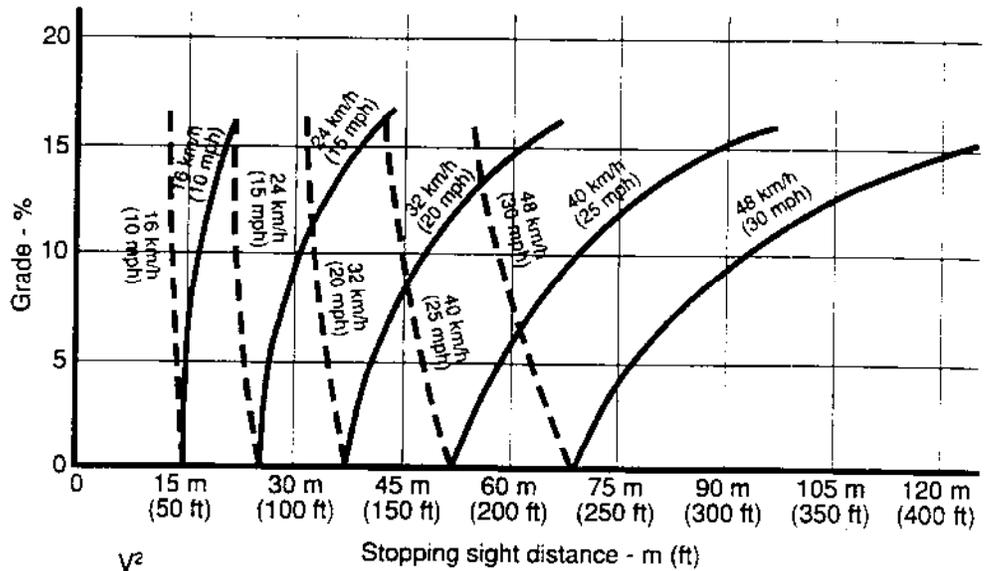
The design of a facility should provide the sight distance adequate for a rider to bring their bicycle to a controlled stop. This distance will be a function of the speed of a bicycle, the braking ability of the bicycle, the coefficient between the tires and the surface, and the bicyclist's reaction time. Figure 28 provides the AASHTO guidelines for minimum stopping distances for different design speeds and grades associated with bicycle paths. The calculations are based on a bicyclist's perception and braking reaction time of 2.5 seconds and a coefficient of friction of .25. Further, Figure 29 provides the AASHTO stopping sight distance at various speeds on crests and Figure 30 provides the AASHTO generated sight distances for line-of-sight obstructions on crests or vertical curves.

Radius	Additional Pavement Width
0 - 7.5m (0 - 25ft)	1.2m (4ft)
7.5 - 15m (0 - 25ft)	.9m (3ft)
15 - 22.5m (0 - 25ft)	.6m (2ft)
22.5 - 30m (0 - 25ft)	.3m (1ft)
30m +	(0ft)



Source: (12).

Figure 27. Example of Widening the Pavement on the Inside and Outside of a Curve



$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Where: S = Stopping sight distance - ft
 V = Velocity - mph
 f = Coefficient of friction (use 0.25)
 G = Grade - rise/run

Descend (-G) ———
 Ascend (+G) - - -

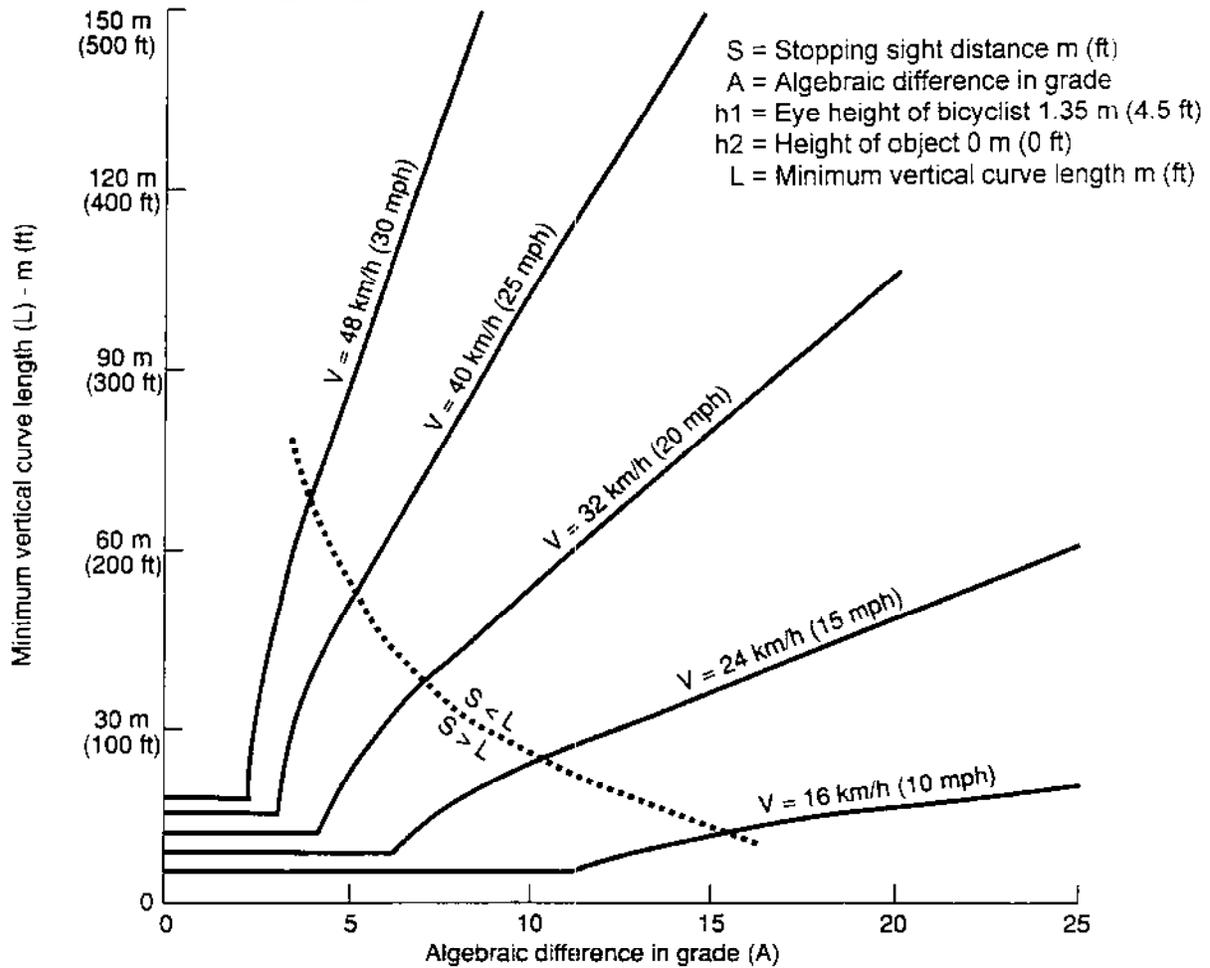
Source: (11).

Figure 28. AASHTO Guidelines for Stopping Sight Distances on Bicycle Paths at Different Speeds

$$L = 2S - \frac{200 (\sqrt{h_1} + \sqrt{h_2})^2}{A} \text{ When } S > L$$

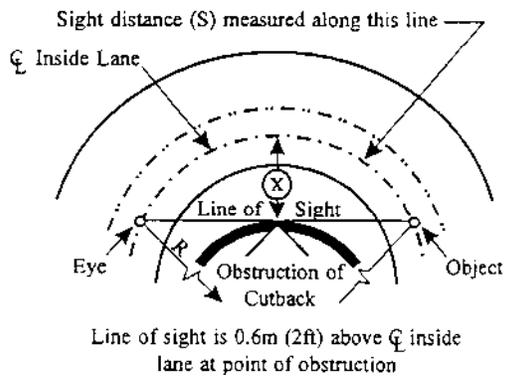
$$L = \frac{AS^2}{100 (\sqrt{2h_1} + \sqrt{2h_2})^2} \text{ When } S < L$$

$$L_{MIN} = 2V$$



Source: (11).

Figure 29. AASHTO Guidelines for Sight Distances for Crest or Vertical Curves on Bicycle Paths



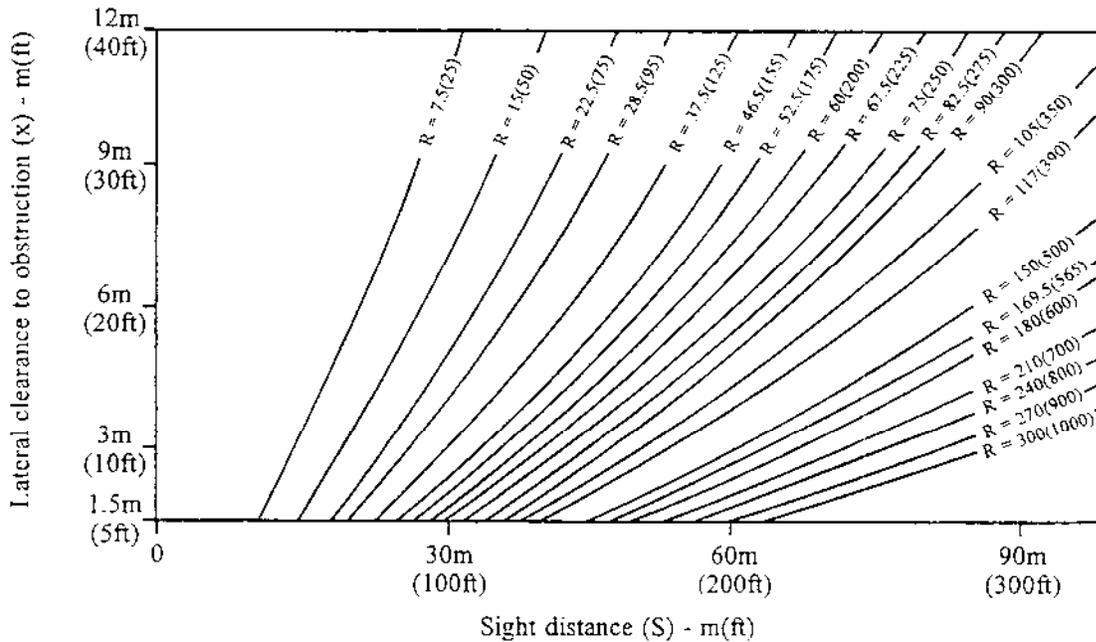
S = Sight distance in meters (feet)
 R = Radius of C inside lane in meters (feet)
 X = Distance from C inside lane in meters (feet)
 V = Design speed for S in km/h (mph)

Angle is expressed in degrees

$$X = R \left[\text{vers} \left(\frac{28.65S}{R} \right) \right]$$

$$S = \frac{R}{28.65} \left[\cos^{-1} \left(\frac{R - X}{R} \right) \right]$$

Formula applies only when S is equal to or less than length of curve.



Source: (11).

Figure 30. AASHTO Guidelines for Lateral Clearance on Horizontal Curves on Bicycle Paths

The information in Figure 28 can be used to identify the appropriate stopping sight distance at various speeds. The sight distance in the descending direction (-G) should be used for two-way paths. In addition, an eye height of 1.35 m (4.5 feet) is usually used as the average for a bicyclist. The object height is also assumed to be zero. The desired lateral clearance can be developed by first identifying the appropriate stopping sight distance using Figure 28. This number is then used in Figure 29 along with the proposed horizontal radius of curvature to identify the desired lateral clearance.

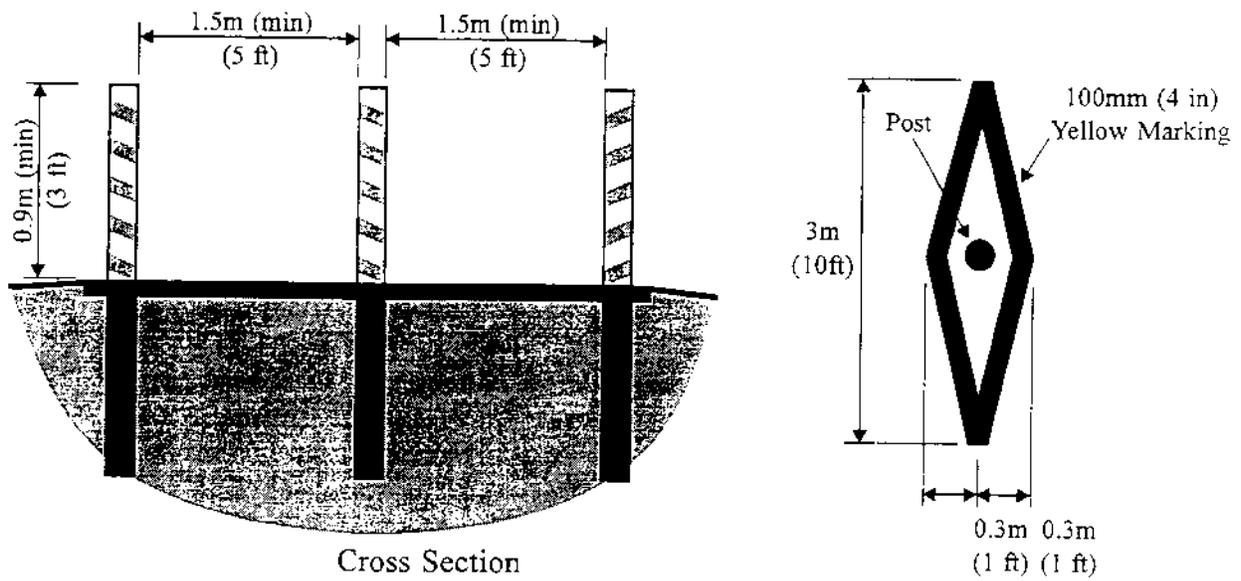
Special attention should be given to lateral clearances and stopping sight distances on curves for two reasons. First, bicyclists frequently ride abreast on paths and trails. Second, there is a natural tendency, especially on narrow paths, to ride near the middle of the trail. To avoid head-on collisions, the sum of the stopping sight distances for bicycles traveling in the opposite directions around a curve should be used to determine the lateral clearance on horizontal curves. If this design is not possible, other measures should be considered. These may include widening the path through the curve, using an MUTCD-approved warning sign or pavement marking, or using a combination of techniques.

Special Barriers to Restrict Motor Vehicles

In some cases, consideration may be given to ensure that motor vehicles not gain access—either unintentionally or intentionally—to a bicycle path or multi-use trail. The possibility of motor vehicles accessing a bicycle trail may be higher if there are at-grade intersections or other connections with existing roadways. Some type of physical barrier can be used to guard against the potential of unauthorized motor vehicles entering a bicycle or multi-use path. Care should be taken in the design of these barriers, however, to minimize possible safety issues for bicycles and other users.

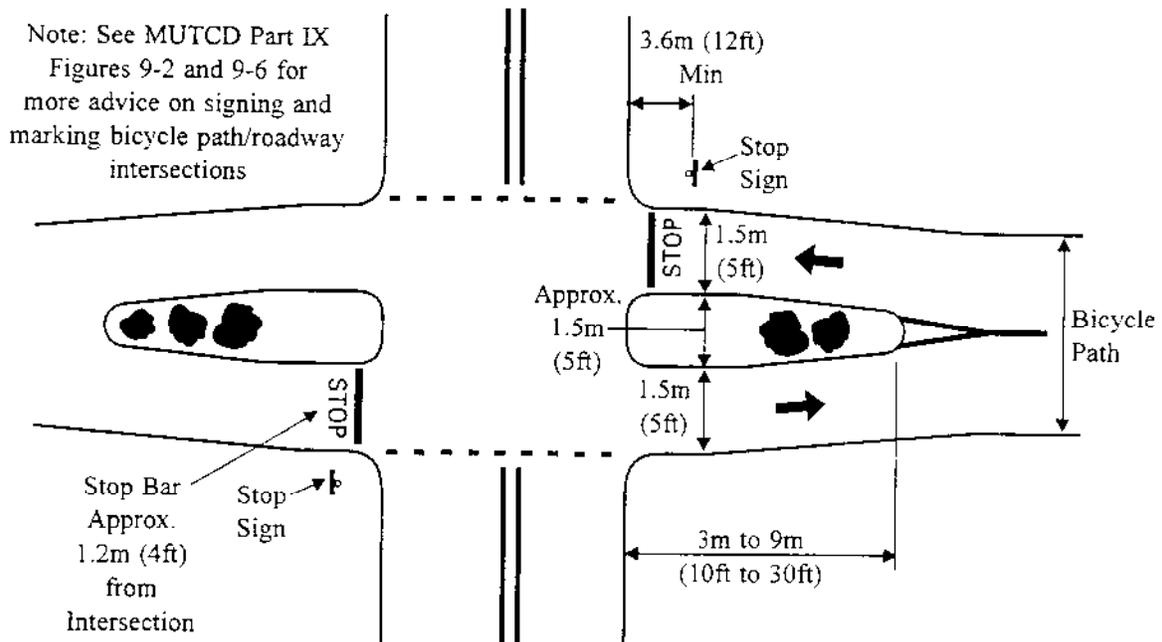
Figure 31 provides an example of the post barriers and pavement markings used by the California Department of Transportation (Caltrans) to restrict motor vehicle access to bike and pedestrian paths. Lockable, removable posts can also be used to allow entry by authorized vehicles. In either case, posts at least .9 m (3 feet) high with bright color reflector material are suggested to improve both daytime and nighttime visibility. The spacing between posts should be approximately 1.5 m (5 feet). This spacing provides adequate width for bicycles and pedestrians while preventing access by automobiles. This spacing will not limit motorcycles, but it is almost impossible to prevent access by this type of vehicle.

A second approach, used by the Ohio Department of Transportation, is shown in Figure 32. This technique uses a split entryway with low landscaping between and adjacent to the bicycle lanes. Authorized vehicles can access the path by driving over the landscaping. Adequate sight distance and lighting should be provided with both approaches to ensure that the barriers are visible from all directions. Advance signing and pavement markings in accordance with the MUTCD should also be provided.



Source: (6).

Figure 31. Refectorized Post to Restrict Motor Vehicles from Bicycle Paths



Source: (9).

Figure 32. Berm and Vegetation to Restrict Motor Vehicles from Bicycle Paths

Drainage

Proper drainage is important for the safe operation and maintenance of bicycle paths and multi-use trails. Using a cross slope of two percent should provide for adequate drainage in most situations. Sloping the path or trail in one direction, rather than crowning it is usually easier. Curves should be sloped toward the inside.

Lighting

Lighting may be appropriate along a bicycle path or multi-use trail depending on the location, the groups anticipated to use the facility and their trip purposes, and the origins and destinations served by the facility. For example, lighting is provided on many existing bicycle or multi-use paths that serve commuters or college students. Lighting is also desirable at intersections or other locations where bicycles and pedestrians are likely to interact with motor vehicles.

INTERSECTIONS

Bicycle paths and multi-use trails, especially those in urban areas, may have to cross a street or a roadway. These crossings should occur on lower volume roadways, whenever possible. If the crossing occurs along a roadway, signing and pavement markings in accordance with the MUTCD should be provided along the roadway and the trail. Adequate stopping space should also be provided for bicycles and pedestrians at the side of the road, as well as a center refuge if needed. A crossing may also be provided at a signalized intersection. In this case, adequate sight distance, along with appropriate signing and pavement markings, should be provided for all users. In both cases, the approaches to at-grade crossings should be level.

STRUCTURES

Bridges and tunnels or underpasses may be used if a bicycle or multi-use path must cross a roadway, freeway, railroad track, river, or other barrier. A grade separation facility represents the only logical alternative to cross a freeway or a river. In addition, since bicycle paths and multi-use trails are intended to be exclusive facilities, grade-separated bridges, overpasses, or underpasses may be considered in other situations. Providing bridges or tunnels can add significantly to the capital cost of a project, however, so the need for these facilities should be carefully evaluated.

Bridges

Two general approaches can be used when bridges are needed along bicycle paths and multi-use trails. The first technique is to provide a new bridge for the exclusive use of bicyclists and pedestrians. The second strategy is to use an existing bridge. The elements that should be considered with these two approaches are described below.

Bicycle or Multi-Use Bridges. A width of 3 m (10 feet) to 4.2 m (14 feet) is suggested for a special bridge associated with a bicycle or multi-use path. These widths provide adequate

space for bicycles, joggers, walkers, and rollerskaters to safely negotiate the crossing. Railings, fences, or some type of barrier at least 1372 mm (54 inches) high should be provided on both sides of the structure. In addition, 250 mm (10 inch) rub rails may be added to the barriers at the height of most bicycle handlebars, which is 1.1 m (3.5 feet). It is also recommended that the railing ends be offset from the adjoining path to minimize the danger of cyclists running into them or some type of warning sign should be provided. Figure 33 provides an example of a bicycle path bridge cross section and railing design from North Carolina.

The anticipated weight or load should be evaluated in the design of bridges along a bicycle path or multi-use trail. A live load design standard of 4070Pa (85 psf) can be used for a bicycle or multi-use facility. Consideration should also be given to the surface used on the bridge and the connection of the bridge to the path or trail. The information provided in Chapter Three on transition zones is applicable with bicycle paths as well.

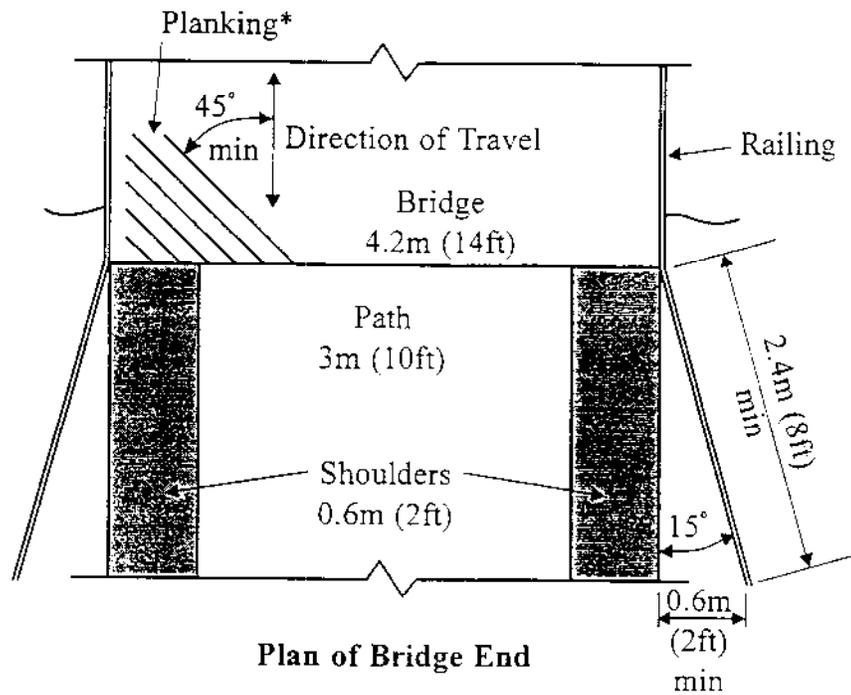
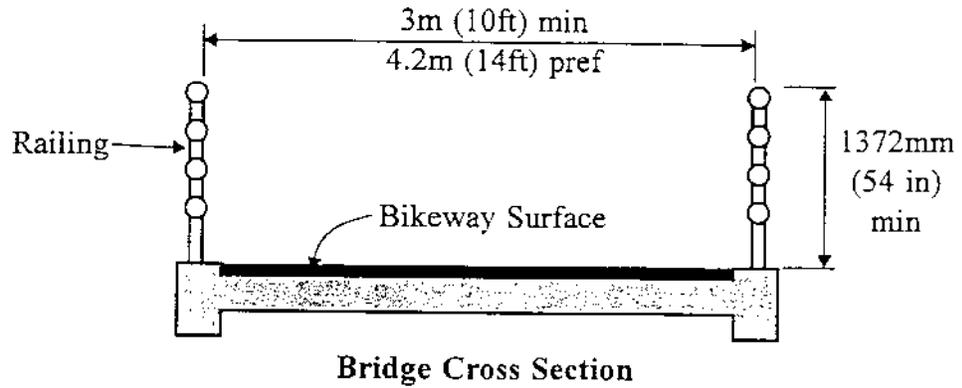
Shared Use of Existing Bridges. A second option for crossing a major roadway, river, or other facility is to use an existing bridge. In this case, the bicycle or multi-use path would join the road or approach to the bridge, use a separate lane or wide lane to cross the bridge, and return to the trail on the other side. The guidelines provided in the previous chapter can be used in this situation. In addition, sidewalks should be provided if pedestrians will be using the bridge.

Underpasses and Tunnels

In some cases, constructing a new underpass or using an existing underpass or tunnel may be appropriate. Figure 34 provides an example of a bicycle path underpass design used by the Arizona Department of Transportation. A width of 3 m (10 feet) to 3.6 m (12 feet) is suggested, with a vertical clearance of 2.4 m (8 feet) to 3 m (10 feet). The guidelines provided in the previous chapter can be used if a bicycle path will connect with an existing roadway tunnel.

SIGNING AND PAVEMENT MARKING

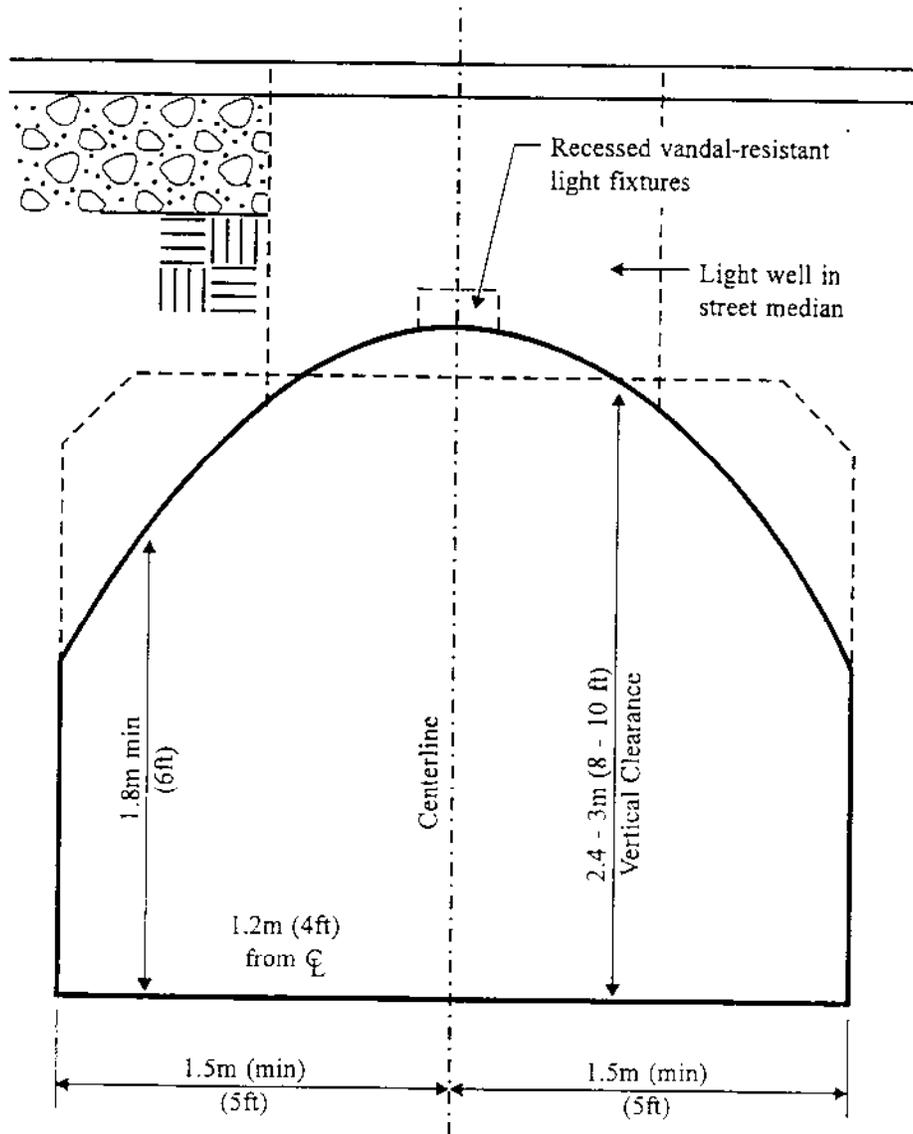
Appropriate signing and pavement markings should be used with bicycle and multi-use paths and trails should be appropriately signed and marked. In addition, correct signing and markings should be used on roadways that will intersect with these facilities. These signs and pavement markings serve a number of purposes. They communicate critical information to bicyclists and pedestrians on potential hazards, use requirements, directions, destinations, distances, and crossings. Signings and markings also alert motorists of an upcoming bicycle and pedestrian crossing or other facility.



* If planking used, it must be laid at least 45° to direction of travel.

Source: (9).

Figure 33. Example of Bicycle Path Bridge Cross Section from North Carolina



Source: (5).

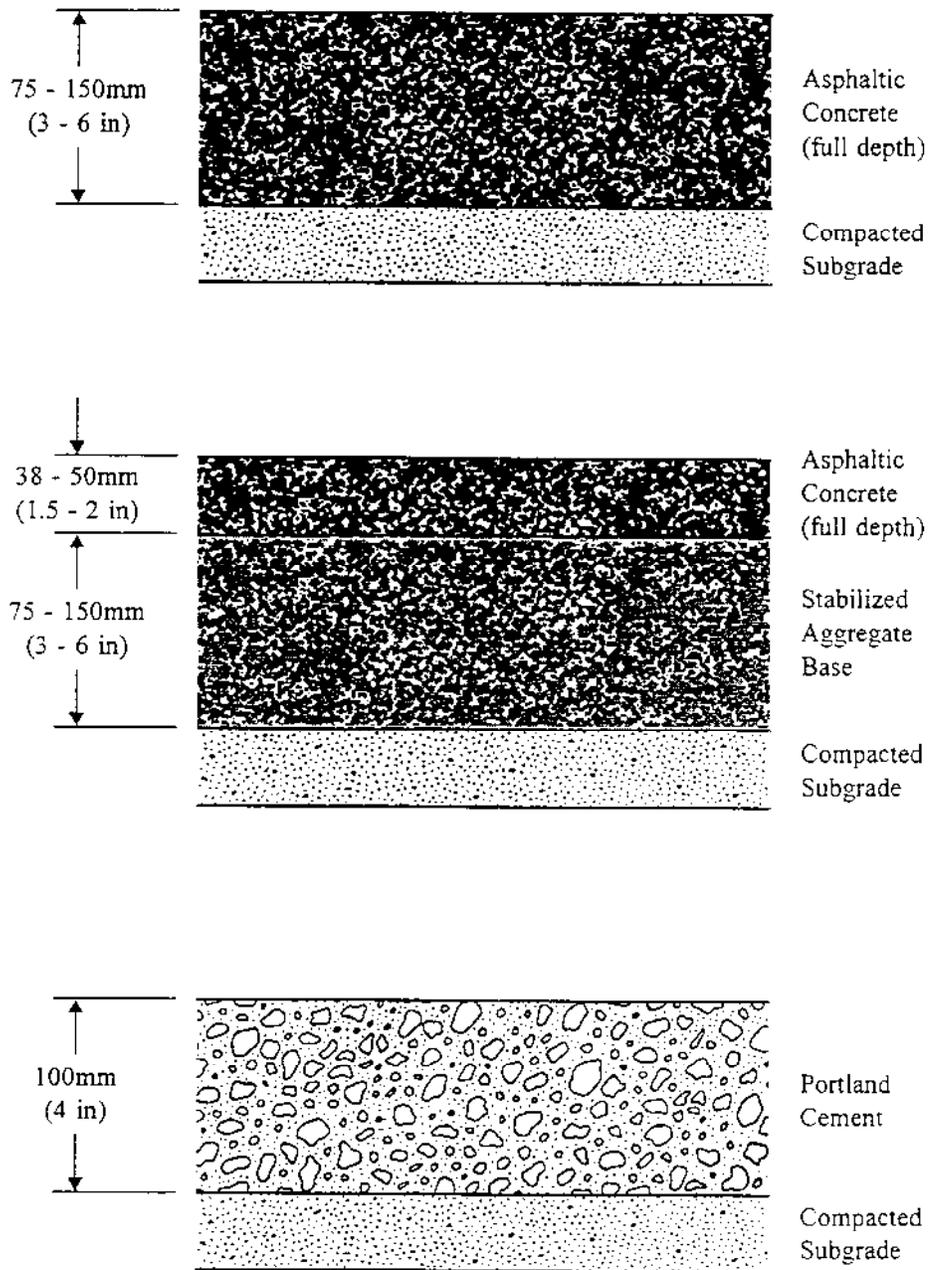
Figure 34. Example of Bicycle Path Underpass Design from Arizona

The same criteria used with locating signs along a roadway should be applied along a bicycle or multi-use trail. Part IX of the MUTCD provides guidance on signing and pavement markings for bicycle facilities. For example, a dashed yellow line, 100 mm (4 inches) to 150 mm (6 inches) wide, should be used to separate bicycle travel lanes. A solid double yellow center line should be used on curves. In addition, white edge lines, 100 mm (4 inches) to 150 mm (6 inches) may be used, especially if high levels of evening or nighttime traffic are anticipated. The pedestrian portion of a multi-use path should be separated from the bicycle lanes by a 100 mm (4 inch) to 150 mm (6 inch) solid white line. If adequate right-of-way is available, the pedestrian path may be separated from the bicycle lane by a berm.

PAVEMENT

A number of factors should be considered in determining the appropriate pavement for use with a bicycle path or multi-use trail. In general, selecting the pavement material for a bicycle or multi-use facility should follow the same process as that which would be used with a roadway in the area. The soil conditions should be examined to identify the load carrying capabilities and any special requirements that may be needed. If motor vehicles will be accessing the facility, extra edge support will be required.

As noted in the previous chapter, the surface of a bicycle facility should be smooth to provide a safe and comfortable riding environment. A variety of pavement materials can be used for bicycle and multi-use trails. Asphalt, concrete, and crushed aggregate represent alternatives that may be appropriate for bicycle and multi-use facilities. The local standards for soil preparation, loads, materials, and construction practices, along with a review of the intended user groups, should be followed in determining the best pavement structure to use with a bicycle path. Figure 35 provides three examples of pavement materials used by the Arizona Department of Transportation in designing bicycle facilities.



Source: (5).

Figure 35. Examples of Pavement Structures for Use with Bicycle and Multi-Use Trails in Arizona

CHAPTER FIVE—DESIGN ELEMENTS OF PEDESTRIAN FACILITIES

This chapter presents general design guidelines for pedestrian facilities. Design considerations associated with sidewalks and intersections are highlighted. Information on pedestrian amenities is also provided. The design features related to multi-use trails, which may be used by pedestrians, were highlighted in Chapter Four.

The Americans with Disabilities Act (ADA) of 1991 (18) will influence the design of pedestrian facilities. The ADA represents a far reaching federal law that prohibits discrimination against individuals with physical or mental disabilities. The Act, and subsequent rules promulgated by multiple federal agencies, contain specific requirements related to employment, accessibility of buildings and facilities, the provision of public transit services, and other elements. The Act, and regulations issued by the Department of Transportation and the Architectural and Transportation Barriers Compliance Board, cover many elements related to sidewalk and pedestrian facilities.

SIDEWALK DESIGN CONSIDERATIONS

The design elements of a sidewalk will depend on a number of factors. These include the roadway classification, adjacent land uses, anticipated pedestrian flows, the ADA, and local regulations. The AASHTO *Policy on Geometric Design of Highways and Streets or Green Book* provides the following guidance on the use of sidewalks in different areas (19).

- Sidewalks should be located as far as practical from the traffic lanes.
- Sidewalks should be provided on both sides of the street in commercial areas. Sidewalks within commercial areas should be 1.5 m to 2.4 m (5 feet to 8 feet) in width.
- Sidewalks are desirable on both sides of the street in residential areas, but may be provided on just one side. The width of sidewalks in residential areas should be 1.5 m (5 feet).
- Sidewalks should be provided along both sides of urban collector streets used for pedestrian access to schools, parks, shopping areas, transit stops, and other activity centers. The width of sidewalks in these areas should be 1.5 m to 2.4 m (5 feet to 8 feet) and should be located as far as practical from the traffic lanes.

Table 6 provides more detailed information on the desired sidewalk width by roadway functional classification and land use from the AASHTO *Green Book*. Local land use plans, zoning ordinances, and subdivision ordinances should also be consulted in designing sidewalks. These plans and ordinances may contain additional requirements relating to the location and design of sidewalks.

Table 6. Desired Sidewalk Widths by Roadway Functional Classification and Land Use

Functional Classification (Urban)	Land Use/Street Configuration			
	# of Through Lanes	CBD	Commercial/Retail	Residential
Principal Arterial	Unobstructed Sidewalk Width in Meters (Feet)			
2	1.52 m (5 ft) to PLOS	1.52 m (5 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
4	1.83 m (6 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
6	2.13 m (7 ft) to PLOS	2.13 m (7 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
8	2.44 m (8 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
Minor Arterial				
2	1.52 m (5 ft) to PLOS	1.52 m (5 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
4	1.83 m (6 ft) to PLOS	1.52 m (5 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
6	2.13 m (7 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
8	2.44 m (8 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m to 2.44 m (5 ft to 8 ft)
Collector				
2	1.52 m (5 ft) to PLOS	1.52 m (5 ft)	1.52 m (5 ft)	1.52 m (5 ft)
4	1.83 m (6 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m (5 ft)
6	2.13 m (7 ft) to PLOS	1.83 m (6 ft)	1.52 m (5 ft)	1.52 m (5 ft)
Local				
2	1.52 m (5 ft) to PLOS	1.52 m (5 ft)	Local Code	1.52 m (5 ft)
4	1.83 m (6 ft) to PLOS	1.52 m (5 ft)	Local Code	1.52 m (5 ft)
6	2.13 m (7 ft) to PLOS	1.52 m (5 ft)	Local Code	1.52 m (5 ft)

Source: (2,14,18,19).

INTERSECTIONS

A number of elements should be considered with sidewalks and other pedestrian facilities at intersections. As discussed in this section, these include crosswalks, corner treatments, and the timing of traffic signals.

Crosswalks

Crosswalks should be provided at intersections where pedestrians are allowed to cross. Crosswalks should be designed to provide the shortest direct distance between opposite sides of the street. Two parallel lines 150 mm to 600 mm (6 inches to 24 inches) wide and 1.5 m (5 feet) apart should be painted across the intersection to delineate the crosswalk. Adequate lighting should be provided at crosswalks to allow pedestrians to cross safely and to allow drivers to see pedestrians.

Adequate sight distance for all users—pedestrians, bicyclists, and motor vehicles—is required at intersections. The sight distance will depend on the speed, distance, perception and reaction time, and visual capacity of each user group. Figures 36 and Figure 37 provide examples of the sight triangles at intersections from the AASHTO *Green Book*. Figure 36 illustrates the speed and distance factors in determining sight distance. As speed increases, the distance (represented by d_a and d_b) also increase. As speed increases, the distance a and b must also increase to provide a safe stopping distance.

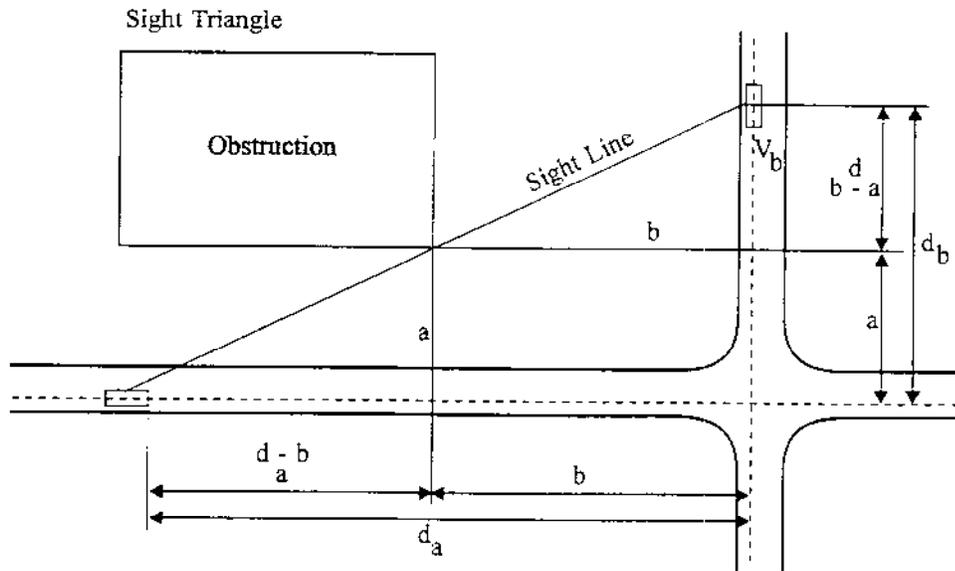
Obstructions at an intersection may include buildings, on-street parking, signs, turning vehicles, utility or signal poles, newspaper machines, and other elements. A general guide to determine the required sight triangle is to maintain a clear zone of 1.5 m (5 feet) from the tangent of the curb radii.

Sidewalk Curb Cuts

The ADA establishes standards for pedestrian ramps and curb cuts, including requirements that new sidewalks connect to the street with a ramp or curb cut. Figure 38 provides an illustration of cross-slope and dimensions for a sidewalk curb cut to the street. In addition, a 1.5 m by 1.5 m (5 feet by 5 feet) flat area or pad is required at the top of each ramp. Further, two ramps must be provided at a corner on a new facility to allow individuals to use the appropriate crosswalk. Figure 39 illustrates the correct and incorrect approaches to meet the ADA requirements. As illustrated, at least 0.6 m (2 feet) of the ramp must be on the tangent of the curb to ensure that pedestrians are not directed into traffic.

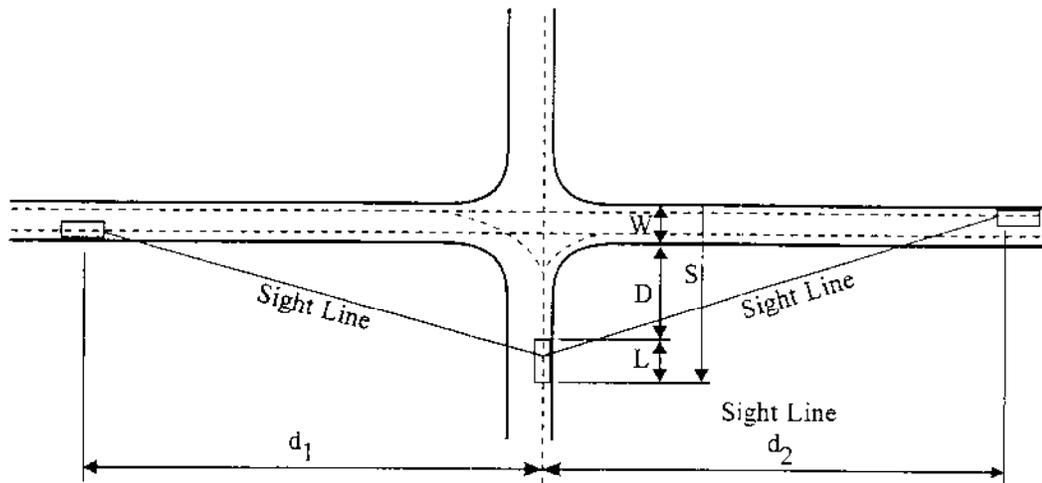
Bulbout and Center Island

Design treatments can be used at intersections to improve sight distance, increase the visibility of pedestrians, and reduce the distance pedestrians have to walk to cross the street. Figure 40 and Table 7 show the affect different corner radii have on pedestrian crossing distances. Bulbout and center or right-turn islands represent two approaches that can be used to shorten the distance at an intersection or to provide a safe waiting area for pedestrians. Figures 41-43 provide examples of these treatments. Figure 42 illustrates a mid-block crossing with a 45 degree angled center median which provides pedestrians with a better view of oncoming traffic.



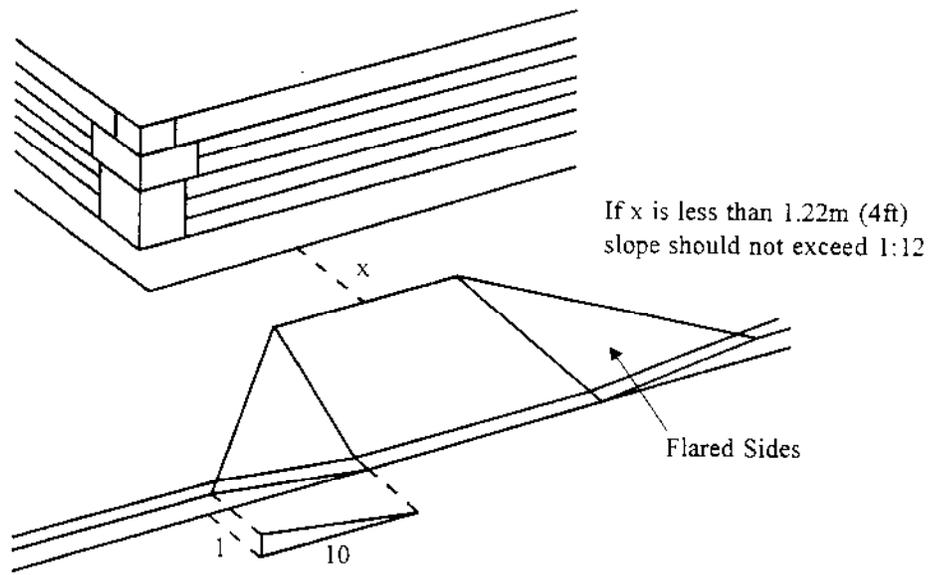
Source: (19).

Figure 36. AASHTO Sight Triangles - No Control or Yield Control on Minor Roadways (Case I and II)



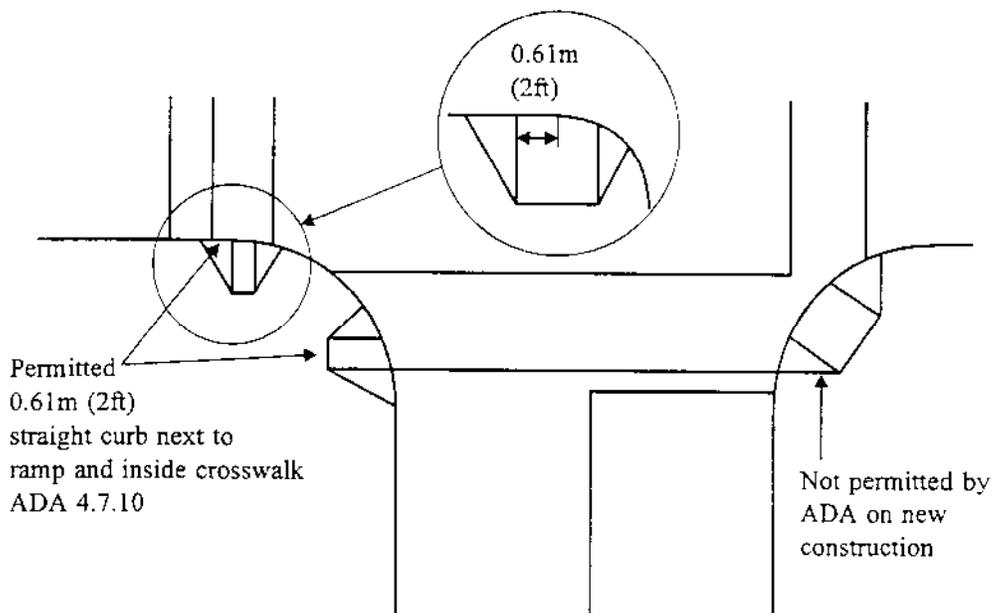
Source: (19).

Figure 37. AASHTO Sight Triangles - Stop Control on Minor Roadways (Case III)



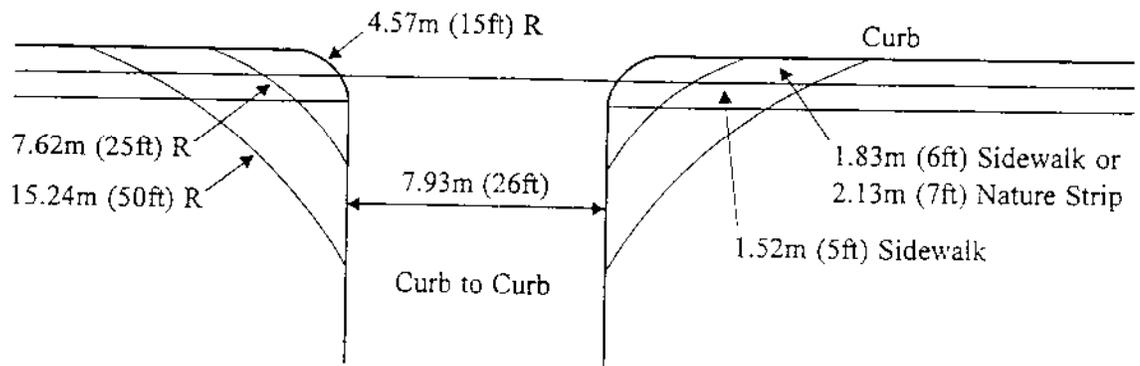
Source: (19).

Figure 38. Cross -slope and Ramp or Curb-cut Dimensions



Source: (19).

Figure 39. Curb Ramp or Curb-cut Location



Source: (7).

Figure 40. Effect of Corner Radii on Pedestrian Crossing Distance

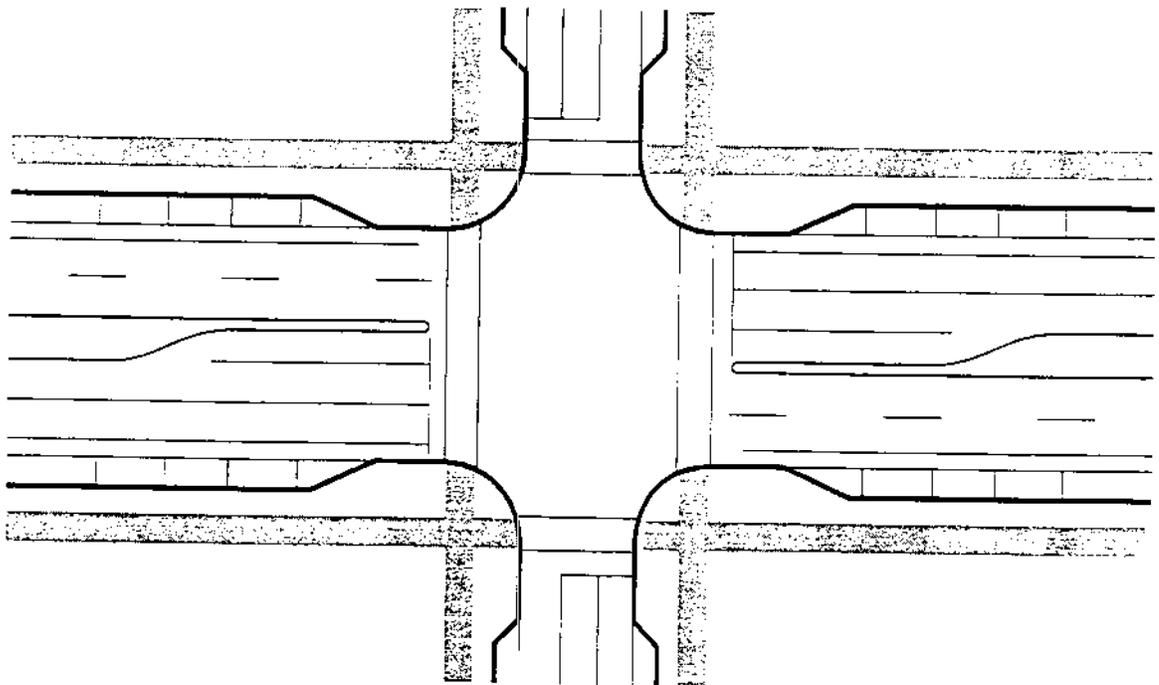


Figure 41. Example of Bulbout at Intersection

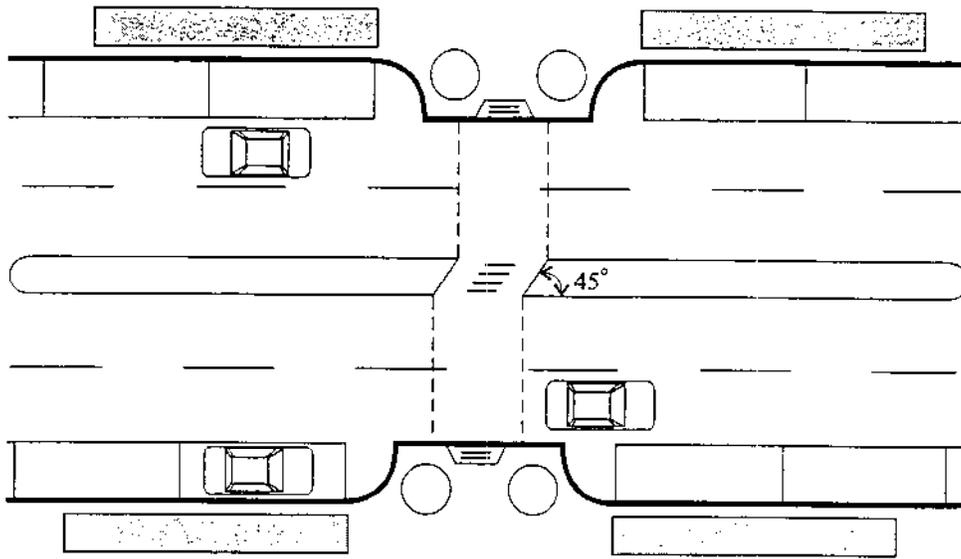


Figure 42. Example of Mid-Block Bulbout

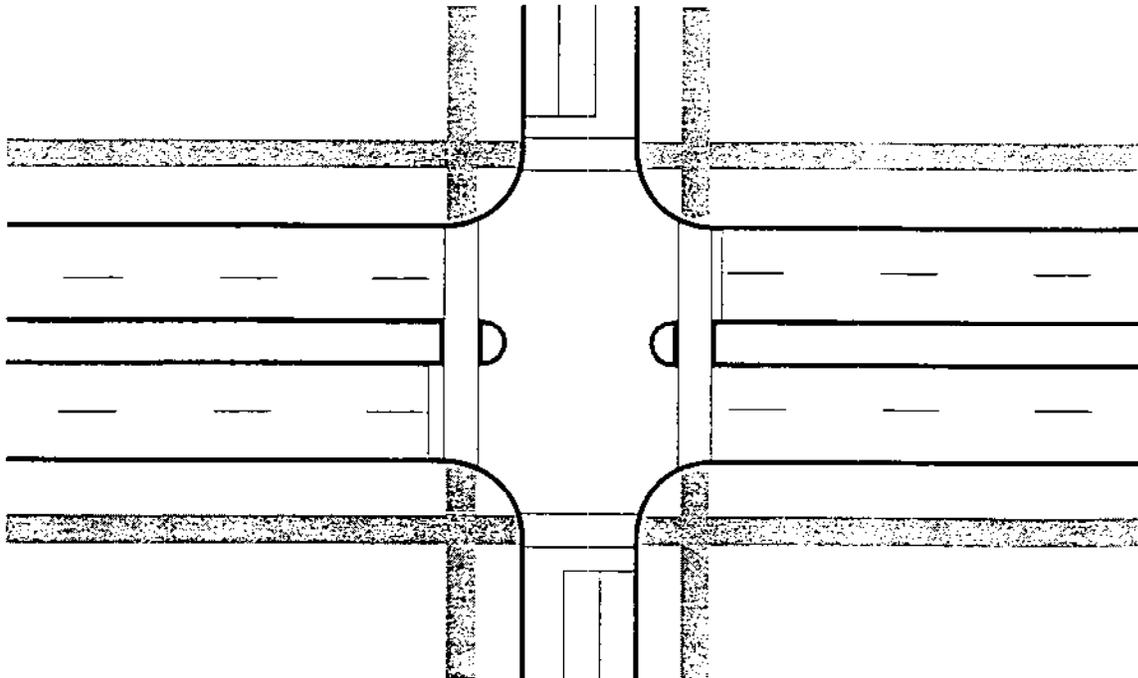


Figure 43. Example of Center Island

Table 7. Cross Distance of Different Corner Configurations

Radius	Cross Distance	Increased Crossing	Percent Increase
4.5 m (15 feet)	7.9 m (26 feet)	+0 m (+0 feet)	0%
7.6 m (25 feet)	11 m (36 feet)	+3 m (+10 feet)	38%
15.2 m (50 feet)	19.8 m (65 feet)	+11.9 m (+39 feet)	150%

Sidewalk at back of curb:

Radius	Cross Distance	Increased Crossing	Percent Increase
4.5 m (15 feet)	11.3 m (37 feet)	+3.3 m (+11 feet)	42%
7.6 m (25 feet)	15.2 m (50 feet)	+7.3 m (+24 feet)	92%
15.2 m (50 feet)	27 m (89 feet)	+16.1 m (+53 feet)	203%

Source: (20).

Bulbouts provide additional space for pedestrian waiting areas, landscaping, and street furniture. They also shorten the distance a pedestrian must walk to cross the street. Figure 41 provides an example of a bulbout at an intersection, while Figure 42 illustrates a mid-point treatment.

Right-turn and center islands can also be used to provide additional safety to pedestrians by providing a safe waiting area. Figure 43 provides an example of a center island. Right-turn islands can provide pedestrians with shorter walking distances, reduce the minimum signal green time, and provide free right turns for motor vehicles. Center islands can provide a mid-point safe waiting area for pedestrians and reduce the minimum signal green time. The design of both types of islands should meet the MUTCD and AASHTO guidelines.

Signal Timing

The timing of traffic signals at an intersection should allow for pedestrians to safely cross the street. A walk time of four to seven seconds and a pedestrian walking speed of 1.2 mps (4 fps) is often used as a guide for timing traffic signals. The Walk Phase should allow an individual to react and leave the curb. The flashing Don't Walk phase should be long enough to allow an individual to leave the curb at the start of this phase and safely cross the street or reach a center island.

The pedestrian groups should be considered in the development of the traffic signal timing plan. Extra walk time should be given in areas with large elderly populations or special user groups.

Walking speeds as low as 0.91 mps (3 fps) may be used to establish signal timing plans in these cases.

Pedestrian and Street Scape Amenities

A variety of amenities can make use of sidewalks, walkways, and paths more enjoyable, and may lead to increased use of the facilities. Pedestrian amenities include elements such as benches, trash cans, and street trees. Other features found on pedestrian facilities that serve different modes of transportation may include transit shelters, parking meters, roadway signs, and street lights.

All these items have benefits if placed and maintained properly. If improperly placed, these items can obstruct travel and become hazardous. Common pedestrian facility and street scape amenities are listed below:

- ATM Machines,
- Benches,
- Bicycle Racks,
- Telephone Booths,
- Maps,
- Newspaper Racks,
- Planters,
- Sidewalk Widening,
- Street Lights,
- Street Art,
- Fountains, and
- Bus Shelters.

Maintenance

Maintenance plays an important role in the operation of a pedestrian system. Proper maintenance can increase effectiveness, service life, degree of use, and community image, and can reduce the potential of liability issues. Repair of apparent structural problems in a timely fashion will lengthen the facility's life. Vandalism in the form of stolen or defaced signs, graffiti, and broken lighting fixtures provides a poor impression to users if not quickly corrected. Perceptions of a lack of security and fear for personal safety may result in decreased use of a facility.

CHAPTER SIX—SUPPORTING FACILITIES AND SERVICES

The provision of supporting facilities and services can make bicycling and walking more attractive alternatives to individuals for commute trips and recreation travel. Bicycle racks or bicycle lockers at employment locations, major activity centers, and transit park-and-ride lots are commonly used to support bicycle travel. Bicycle racks on public transit buses, allowing bikes on rail transit vehicles, and providing showers and changing facilities at work sites represent other examples. Elements to consider in the use of supporting facilities and services are highlighted in this chapter along with case study examples from Texas and other parts of the country.

BICYCLE RACKS AND LOCKERS

Safe and convenient parking areas for bicycles is an integral component of an overall bicycle plan. Individuals will be more likely to use bicycles for commute and recreation trips if secure bicycle parking areas are available at both the origin and the destination. Further, without the provision of bicycle racks, lockers, or other facilities, individuals may use trees, railings or street furniture to secure their bicycles. This practice may cause hazards for pedestrians, as well as damaging these items. The use of different bicycle securement devices and parking facilities is highlighted in this section.

Planning and Selecting Bicycle Securement Devices

A number of elements should be considered in planning and selecting the most appropriate type of bicycle securement device and bicycle parking area. Key factors to be included in this process are the bicycle user groups and trip purposes being served, the physical characteristics of the area, ease of use, the level of security desired, the anticipated number of users, the potential for expansion, and the local conditions.

Bicycle User Groups and Trip Purposes. The type of bicycle users and their trip purposes will influence the selection of bicycle securement devices and parking areas. For example, individuals using bicycles for commuting, recreation, errands, and other trip purposes will have different needs related to securing their bicycles. Individuals who ride their bicycles to work will need long-term parking at their destination, while bicyclists on recreational trips or errands are more likely to need shorter-term parking.

Physical Characteristics of the Area. The physical characteristics of an area may influence the type of bicycle securement device. Different approaches will probably be needed in older commercial areas, new suburban shopping centers, employment locations, schools and universities, and recreational areas. Elements that may influence the selection process include the amount of space needed, other fixtures in the area, requirements or setbacks from buildings, and ensuring that conflicts with pedestrians and vehicles are avoided.

Ease of Use and Convenience. Bicycle parking areas and securement devices should be easy to use. Complicated securement devices may not be understood by some user groups. In addition, bicycle parking areas should be conveniently located to serve the needs of the targeted population.

Level of Security. The type of securement device and the location of a bicycle parking area will be influenced by the desired level of security. Security may be less of a concern with short-term bicycle parking areas at retail establishments or recreational areas. Bicycle racks or other securement devices may be appropriate in these locations. Providing higher levels of security may be more important at longer-term bicycle parking facilities oriented toward work or school trips. Bicycle lockers or other techniques which provide a higher level of security and reduce the potential for theft or vandalism should be used in these areas. Lighting and other elements can also enhance the security of bicycle parking areas.

Anticipated Number of Users. The type of bicycle parking provided at a location will be influenced by the anticipated number of users. Relatively simple bicycle racks may be appropriate for short-term parking in areas of low demand. Other techniques may be considered in situations where heavy use is anticipated.

Expansion Potential. The potential for future expansion of the bicycle parking area should be evaluated during the planning stage. Identifying additional bicycle storage areas during the initial planning process can provide flexibility to address heavy use of a facility and to assist in avoiding possible conflicts with other groups.

Local Conditions. A wide variety of local conditions may influence the location of bicycle parking areas and the type of security devices used. These may include weather conditions, local policies, land use and zoning requirements, and other elements.

Bicycle Securement Devices and Parking Areas

A number of different types of bicycle securement devices are available. Further, a variety of bicycle parking or storage areas can be provided. Bicycle racks, bicycle lockers, and bicycle stations represent three different approaches that may be appropriate for consideration.

Bicycle Racks. Bicycle racks are the most common form of securement device. Bicycle racks come in a variety of shapes and sizes. The type of rack used in a specific area should be matched with the needs of the anticipated user groups, the space available, and the other elements described previously. Figure 44 provides examples of different types of bicycle racks.

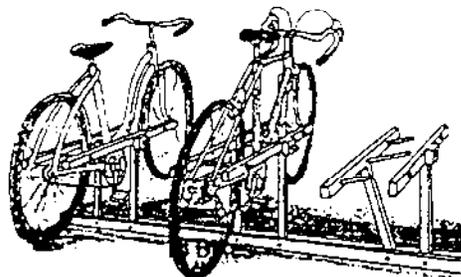
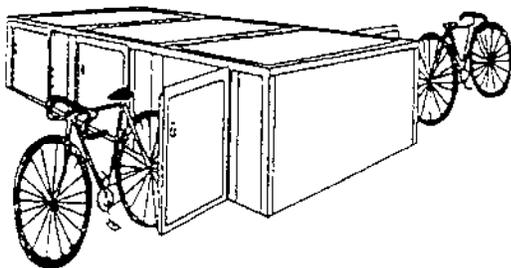
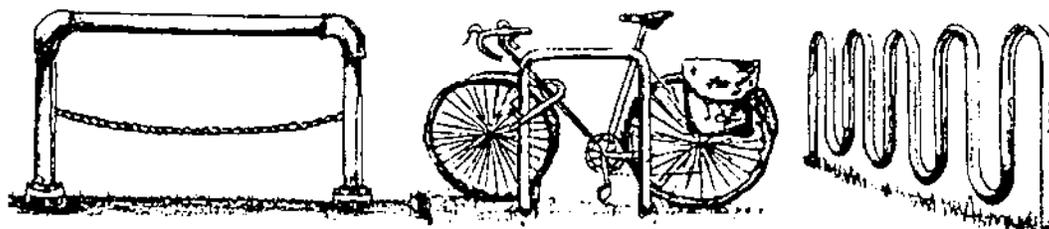


Figure 44. Examples of Bicycle Racks and Lockers

Bicycle Lockers. Bicycle lockers represent a second approach that can be used at bicycle parking areas. As shown in Figure 45, bicycle lockers provide enclosed storage areas for bicycles and riding gear. Bicycle lockers provide a higher level of security than bicycle racks, as well as protection from rain and inclement weather. Bicycle lockers are more expensive than racks. As a result, lockers may be appropriate for consideration primarily where long-term bicycle storage is desired such as transit park-and-ride lots and major employment or activity centers. In some cases, a small fee may be charged for the use of bicycle lockers.

Bike Stations. Bike stations, which provide a range of services to bicyclists, are used in Japan, Holland, and other parts of Europe. As illustrated in Figure 45, the *Bikestation* in Long Beach, California, which was opened in 1996, represents the first use of this technique in the United States. The *Bikestation* provides enclosed, guarded bicycle parking for \$1.00 a day. A \$5.00 monthly parking rate is also available by joining the commuter bicycle club. Other services include bicycle rentals, repairs and maintenance, changing areas, restrooms, a bicycle shop, and a coffee bar. The *Bikestation* is located in the Long Beach Transit Mall in the downtown area. Connections can be made with the Metro Blue Line rail service, Long Beach Transit buses, the Roundabout Shuttle System, and the local bike path network. The facility is owned by the City of Long Beach. The development and operation of the *Bikestation* is being financed by the enhancement program of the ISTEA and local funds.



Figure 45. The Long Beach *Bikestation*, Long Beach, California

BICYCLES AND PUBLIC TRANSPORTATION

Transit agencies, transit operators, and other groups can take a variety of actions to enhance the interaction between bicyclists and public transportation. These may include providing bicycle storage areas at park-and-ride lots, providing bicycle racks on buses, and allowing bicycles on rail

transit vehicles. All of these elements can increase the range of bicycle use for commuting and recreational travel, as well as encouraging greater use of bicycles and public transportation.

Bicycle Facilities at Park-and-Ride Lots. Providing bicycle racks or lockers at park-and-ride lots can encourage greater use of public transportation by bicyclists. These facilities allow individuals to ride their bicycles to a park-and-ride lot, rather than driving their cars or walking. The individual then uses the public transit mode—which could be bus, light rail, heavy rail, or commuter rail—for the major portion of their trip. Most park-and-ride lots include bicycle racks, lockers, or other facilities.

Bicycle Racks on Buses. Providing bicycle racks on buses can also encourage greater use of bicycles and public transit by increasing the range of bicycle use for commuting and recreational trips. As illustrated in Figure 46, bicycle racks are usually mounted on the front of the bus to allow the vehicle operator to monitor their use.

A number of transit agencies throughout the country operate bicycle rack equipped buses on some or all routes. In Texas, Capital Metro in Austin, Houston METRO, and Citibus in Lubbock currently have some bicycle rack equipped buses in service. Other transit agencies are exploring the option or have demonstration projects in the planning stage.



Figure 46. Bicycle Racks on Buses—Houston METRO Brochure

Bicycles on Rail Transit Vehicles. Bicycles are also allowed on some light rail transit (LRT), heavy rail, and commuter rail systems throughout the country. In most cases, bicycles may only be brought on board the rail vehicles during the off-peak travel periods. In addition, bicycles may be limited to specific cars and bicyclists may be required to register or obtain special passes.

ON-SITE FACILITIES

Commuting by bicycle can be supported by the availability of on-site facilities such as showers and changing rooms. Bicycle commuters often wear non-work clothing while riding to and from work. Having an area to change clothes, and possibly shower, makes commuting by bicycle, or by walking, a more convenient and attractive alternative for individuals.

Some companies and public agencies in Texas and other areas of the country provide these types of on-site facilities for their employees. For example, the results of an analysis of the Employer Trip Reduction (ETR) plans submitted by some 1,400 Houston area businesses and public agencies with over 100 employees indicate that approximately 30 percent provide some type of on-site changing areas or shower facilities (21).

CHAPTER SEVEN—IMPLEMENTATION STRATEGIES

This report presents guidelines that can be used for planning and designing bicycle and pedestrian facilities in Texas. A process for planning roadway bicycle lanes, bicycle paths, multi-use trails, and pedestrian walkways is presented. Examples of specific elements for consideration in the planning process are highlighted. Design features associated with wide general purpose roadway lanes, bike lanes, shoulders, bike paths, multi-use trails, and sidewalks are described. Supporting facilities to encourage greater use of bicycle and pedestrian facilities are also outlined.

As discussed in this report, bicycling and walking can have numerous benefits to individuals, the environment, and communities. For these benefits to be realized, however, bicycle and pedestrian facilities will need to become more widespread throughout Texas. The guidelines presented in this report can be used to help plan, design, implement, and operate safe and efficient bicycle and pedestrian projects. TxDOT and other groups may wish to consider implementing the following techniques to help support and promote the use of these guidelines and the development of bicycle and pedestrian facilities throughout the state.

- **Distribution of Guidelines.** TxDOT has an extensive system for distributing research reports within the department. This process ensures these guidelines are provided to the appropriate personnel. TxDOT may also wish to consider distributing the report to MPOs, transit agencies, cities, counties, and other groups in the state with responsibilities for or interest in bicycle and pedestrian facilities.
- **Presentations at Conferences or Workshops.** Another way to help disseminate information on the guidelines is through presentations at conferences and workshops. The TxDOT Transportation Conference, the TxDOT Transportation Planning Conference, the TxDOT Public Transportation Conference, the Texas Chapter of the Institute of Transportation Engineers (TexITE) Winter and Summer meetings, the Texas Chapter of the American Planning Association (APA) Annual Meeting, and conferences sponsored by the South West Transit Association (SWTA) and other organizations all represent opportunities to present the guidelines.
- **Special Workshops or Training Sessions.** A workshop, training course, or seminar could be developed and offered on planning and designing bicycle and pedestrian facilities. The basic elements to consider in planning and designing the various types of bicycle and pedestrian projects could be presented, and case studies from different parts of the state could be highlighted. It might be appropriate to provide a general overview seminar for management level personnel and a more detailed course for personnel responsible for planning, designing, constructing, and operating bicycle and pedestrian facilities. TxDOT, MPOs, transit agencies, communities, and other groups could sponsor these workshops or training sessions.

- **Educational Outreach Programs.** TxDOT, other state agencies, MPOs, transit agencies, communities, and bicycle and pedestrian organizations could develop and implement a statewide educational outreach program on bicycle and pedestrian facilities. Such an effort could be aimed at educating different groups on the safe development and use of bicycle and pedestrian facilities. Pamphlets, brochures, newsletters, flyers, and other methods represent possible techniques to present information on available bicycle and pedestrian facilities, the safe use of these facilities, and key elements in planning and designing these projects. Specific groups—such as children, recreational users, individuals who commute by bicycle or walking, motor vehicle operators, and policy makers—could be targeted for special information or outreach efforts.
- **Technical Assistance.** TxDOT, or other groups, could develop a technical assistance program and provide ongoing support to MPOs, transit agencies, local communities, businesses, and other groups interested in planning, designing, implementing, and operating bicycle and pedestrian facilities. Such a program could be developed and funded at the state, metropolitan, or local level.
- **Video.** A short video could be prepared summarizing the benefits of bicycling and walking, the major elements to consider in planning and designing safe facilities, and case study examples. The video could be used with the training sessions or as a part of the outreach program. It could also be distributed throughout the Department and to other groups with a copy of this report.
- **Establish Peer-to-Peer Network.** TxDOT could establish a peer-to-peer network within the Department as well as among personnel in the Department and staff in other agencies and organizations. This network could provide one-on-one dialog and interaction among personnel working on bicycle and pedestrian projects. Establishing a peer-to-peer network to provide opportunities for staff to talk with their counterparts on specific issues or problems, to share information on techniques and solutions, and to help establish common practices among the various TxDOT Districts and other groups. TxDOT, MPOs, and other groups could help establish and promote these networks.
- **Use of Advanced Technologies.** Electronic mail, the TxDOT home page on the World Wide Web, and video and telephone conferencing could all be used to provide ongoing assistance, education, and outreach efforts to promote bicycle and pedestrian facilities. Consideration could be given to coordinating these activities at the state level, through TxDOT, or at the regional level, through MPOs, transit agencies, and other groups.

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APPENDIX A—GLOSSARY OF BICYCLE AND PEDESTRIAN TERMS

AASHTO: American Association of State Highway and Transportation Officials.

ADA: The Americans with Disabilities Act of 1990.

ADT: Average Daily Traffic. The measurement of the average number of vehicles passing a certain point each day on a highway, road, street, or path.

Arterial Road: A road designated to carry traffic, mostly uninterrupted, through local or neighborhood street system.

Bicycle: A vehicle having two tandem wheels, or having three wheels in contact with the ground, propelled solely by human power, upon which any person or persons may ride.

Bicycle Facilities: A general term denoting improvements and provisions to accommodate or encourage bicycling, including parking facilities, maps, all bikeways, and shared roadways.

Bicycle Lane Bike Lane: A portion of a roadway which has been designated by striping, and pavement markings for the preferential or exclusive use of bicyclists.

Bike Route: A segment of a system of roads and ways that is linked by directional and informational signs to aid bicyclists. Bike routes are highly specific, giving a clear indication of destination.

Bikeway: A thoroughfare suitable for bicycles, either within a roadway right-of-way or along a separate and independent corridor.

Clearance, Lateral: The width required for safe passage of a bicyclist as measured in a horizontal plane.

Clearance, Vertical: The height necessary for the safe passage of a bicyclist as measured in a vertical plane.

Clearance Interval: The amount of time a traffic signal provides to allow a type of traffic to clear the intersection before releasing conflicting traffic.

Collector Road: A road designated to carry traffic between local streets and arterials, or from local street to local street.

Cross Section or “Typical Cross Section”: Diagrammatic presentation of a highway or path profile which is at right angles to the centerline at a given location.

Edge Line: A painted or applied line to designate the edge of the road (10 mm, or 4 inches).

Frontage Road: A road designed and designated to serve local traffic parallel and adjacent to a controlled access roadway.

Grade: A measure of the steepness of a roadway, bikeway, or walkway, expressed as a ratio of vertical rise per horizontal distance, usually in percent. For example, a five percent grade equals a five meter (16.4 ft) rise over a 100 meter (328 ft) horizontal distance.

Grade Separation: The vertical separation of conflicting travelways with a structure. Overpasses or tunnels are examples of common grade separations used to avoid conflicts.

Highway: The entire width between property or right-of-way lines of every way or place of whatever nature, when any part thereof is open to the use of the public as a matter of right for the purposes of vehicular traffic. The terms “highway” and “street” and their cognates are synonymous.

ISTEA: The Intermodal Surface Transportation Efficiency Act of 1991.

Multi-Use Path or Trail (Bike Path, Bike Trail): Any bikeway that is physically separated from motorized traffic by an open space or barrier. It is either within the highway right-of-way or within an independent right-of-way. Due to a lack of pedestrian facilities, most bike paths/trails are commonly designed and referenced as multi-use paths or trails.

MUTCD: The *Manual on Uniform Traffic Control Devices*, approved by the Federal Highway Administration as a national standard for placement and selection of all traffic control devices on or adjacent to all highways open to the public.

Pavement Markings: Painted or applied lines or legends placed on a roadway surface for regulating, guiding, or warning traffic.

Right-of-Way: A general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

Right-of-Way: The right of one vehicle or pedestrian to proceed in a lawful manner in preference to another vehicle or pedestrian.

Roadway: That portion of the highway, including shoulders.

RRR Projects: Specific roadway improvement projects that include resurfacing, restoration, and rehabilitation of roadways. These projects use different funds than those used for new construction.

Rules of the Road: That portion of a motor vehicle law that contains regulations governing the operations of vehicular and pedestrian traffic.

Shared Roadway: Any roadway upon which a bicycle lane is not designated and which may be legally used by bicycles regardless of whether such facility is specifically designated as a bikeway.

Shoulder: That part of a highway which is contiguous to the regularly traveled portion of the highway and is on the same level as the highway; the shoulder may be pavement, gravel, or earth.

Shoulder (Paved): That portion of a highway which is contiguous to the travel lanes, allowing use for emergencies of motor vehicles, for specialized use of pedestrians and bicyclists, and for lateral support of base and surface courses.

Shy Distance: The distance between the edge of a travelway and a fixed object. Also, the separation distance a roadway user needs to feel safe operating near a fixed object.

Sidewalk: The linear portion of highway designed for preferential or exclusive use by pedestrians.

Sight Distance: The distance a person can see along an unobstructed line of sight.

Street: The terms “highway” and “street” and their cognates are synonymous.

Structure: A bridge, overpass, retaining wall, or tunnel.

Traffic Control Devices: Signs, signals, or other fixtures, whether permanent or temporary, placed on or adjacent to a travelway by authority of a public body, having jurisdiction to regulate, warn, or guide traffic.

Traffic Volume: The given number of vehicles that pass a given point for a given amount of time (hour, day, year). See ADT.

Undesignated Bike Lane: That portion of a highway to the right of the edge line that is of sufficient width for a bicyclist to navigate and which has not been marked for bicycling (typically 1.2 m -2.0 m wide). Most rural paved shoulders, and a few urban roads are left undesignated as an engineering judgment.

Vehicle: Any device in, upon, or by which any person or property is or may be transported or drawn upon a highway and includes vehicles that are self-propelled or powered by any means. Does not include in-line skates or roller skates.

Vehicle (Motor): To help differentiate those laws that apply to all vehicles (includes bicycles) versus those for motor vehicles, the term *motor vehicles* is applied.

Wide Curb Lane or Wide Outside Lane: A minimum roadway improvement where the curbside lane is typically widened to 4.2 m (14 ft).

APPENDIX B—EXAMPLE OF POSTCARD SURVEY OF BICYCLISTS AND PEDESTRIANS

The following provides an example of a postcard survey used by TTI researchers to obtain information on bicycle and pedestrian use of selected facilities.

Howdy! The Texas Transportation Institute is conducting a survey of bicyclists and pedestrians for the Texas Department of Transportation. The results of the survey will be used to improve conditions for bicycling and walking in the state of Texas. Please take 5 minutes to answer the following questions, then stick the postcard in any U.S. mailbox. If you have any questions about this survey, please contact Shawn Turner at (409) 845-8829. Thanks for your cooperation.

Where did your trip begin? (closest intersection/building)

What is your final destination? (closest intersection/building)

What is the purpose of this trip? (circle one)

Work Recreation Shopping Personal

Other: _____

Typically, how much time do you spend making this trip?

How many times per week do you make this trip by biking or walking? (count your return trip)

Any other comments?

APPENDIX C—DEPARTMENT OF PUBLIC SAFETY PEDESTRIAN AND BICYCLE TRAFFIC LAWS AND SAFETY GUIDELINES

The following information is reprinted from the *Driver's Handbook*, May 1994, by the Department of Public Safety.

Bicycle Traffic Law

1. "Bicycle" means every device propelled by human power upon which any person may ride, having two tandem wheels either of which is more than 14 inches in diameter.
2. Vehicle means every device, in, upon, or by which any person or property is or may be transported or drawn upon a highway, excepting devices used exclusively upon stationary rails or tracks.
3. A bicycle is a vehicle and any person riding a bicycle has all of the rights and responsibilities as a driver of a vehicle.
4. A bicyclist should always obey all traffic laws, signs, and signals. Never ride opposite the flow of traffic. Stop at all stop signs and stop at (red) lights.
5. Bicyclists are required to ride as far right: in the lane as possible only when the lane can be safely shared by a car and a bicycle, side by side. Even then, there are certain conditions that allow a bicyclist to take the full lane, such as:
 - a. The person is overtaking and passing another vehicle proceeding in the same direction.
 - b. The person is preparing for a left turn at an intersection or onto a private road or driveway.
 - c. There are unsafe conditions in the roadway such as fixed or moving objects, parked or moving vehicles, pedestrians, animals, potholes, or debris.
 - d. The lane is of substandard width making it unsafe for a car and a bicycle to safely share the lane side by side. When this is the case, it is best for the cyclist to take the full lane whether riding single file or two abreast.
6. A person operating a bicycle on a one-way roadway with two or more marked traffic lanes may ride as near as practicable to the left curb or edge of the roadway.

7. Persons riding two abreast shall not impede the normal and reasonable flow of traffic on the roadway. Persons riding two abreast on a laned roadway must ride in a single lane.
8. A person riding a bicycle shall not ride other than upon or astride a permanent and regular seat.
9. No bicycle shall be used to carry more persons at one time than the number for which it is designed or equipped.
10. No person riding a bicycle shall attach the same or himself to any streetcar or vehicle upon a roadway.
11. No person operating a bicycle shall carry any package, bundle, or article which prevents the driver from keeping at least one hand upon the handlebars.
12. Bicyclists may ride on shoulders.
13. Bicyclists may signal a right-hand turn using either the left arm pointing up or the right arm pointed horizontally.
14. Every bicycle shall be equipped with a brake which will enable the operator to make the braked wheels skid on dry, level, clean pavement.
15. Every bicycle in use at nighttime shall be equipped with the following:
 - a. A lamp on the front which shall emit a white light visible at a distance of at least 500 feet to the front.
 - b. A red reflector on the rear of a type approved by the Department of Public Safety which shall be visible from all distances up to 300 feet. A red light on the rear visible from a distance of 500 feet in addition to the red reflector may also be used in addition to the red reflector.
16. Hearing-impaired bicycle riders may display a safety flag.

Bicycle Safety Guidelines

1. Although not required by law, it is highly suggested that bicycle riders wear an approved bicycle helmet.
2. When riding on pedestrian facilities, reduce speed and exercise caution.
3. Do not weave in and out of parked cars.

4. Move off the street to stop, park, or make repairs to your bicycle.
5. A bicyclist should select a route according to the person's own bicycling skill and experience.
6. It is not required by law, but bicycles should be equipped with a mirror.

Wet Weather Riding

The visibility of motorists is greatly decreased. Wear highly visible clothing when riding on a bicycle. Water makes certain surfaces slick. Be aware of manhole covers and painted stripes on the road. Water obscures some hazards. Watch for potholes filled with water.

Common Motorist Mistakes that Bicycle Riders Should Know

1. The most common motorist-caused car-bicycle collision is a motorist turning left in the face of oncoming bicycle traffic. Oncoming bicycle traffic is often overlooked or its speed misjudged.
2. The second most common motorist-caused car-bicycle collision is a motorist turning right across the path of the bicycle traffic. The motorist should slow and merge with the bicycle traffic for a safe right-hand turn.
3. The third most common motorist-caused car-bicycle collision is a motorist pulling away from a stop sign, failing to yield right-of-way to bicycle cross traffic. At intersections, right-of-way rules apply equally to motor vehicles and bicycles.

Pedestrian Safety

- Obey all traffic and pedestrian control signals.
- Do not cross the street between two intersections. It is dangerous to cross in the middle of the block.
- Use sidewalks when available, and do not walk in the street.
- Walk on the left side of the road if there are no sidewalks. Step off the pavement when a car approaches.
- If crossing a street at any point other than within a crosswalk at an intersection, the pedestrian must yield the right-of-way to all vehicles.
- When crossing at a crosswalk, keep right.

- Blind, partially blind, or disabled persons may carry a white cane while walking. Others must not display such a cane on any public street or highway.
- No person may stand in the roadway for the purpose of soliciting a ride, contributions, or business.
- Do not suddenly walk or run into the street. This may make it impossible for an oncoming driver to yield.
- Wait on the curb, not in the street, until the traffic signals change to green or read "Walk".
- Always wear white or light colored clothing, or carry a light or reflector when walking at night.
- Look both ways before crossing the street and before stepping from behind parked cars.
- Be extra careful when getting off a streetcar or bus.
- Get in and out of cars on the curb side of the road.
- Do not walk on a roadway when drinking. Many drinking pedestrians become traffic victims.
- Watch for blind or handicapped persons crossing the street. Texas law states: "The driver of a vehicle approaching an intersection or crosswalk where a pedestrian guided by a guide dog or carrying a white cane is crossing or attempting to cross shall take necessary precautions to avoid injuring or endangering the pedestrian. The driver shall bring the vehicle to a full stop if injury or danger can be avoided only by that action." Remember, the white cane indicates the person may be blind, partially blind, or disabled. Others must not display such a cane on any public street or highway. If you see a blind person, slow down, use your horn if necessary, and be prepared to stop. Watch especially for blind persons at bus stops, intersections, business areas, and near schools for the blind.